Bioventing Design Tool ™

User's Guide

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Abbreviations and Acronyms

AFFCEE   Air Force Center for Environmental Excellence
ASCII   American Standard Code for Information Interchange
BVDT   Bioventing Design Tool
CSV   comma-separated values
HP   horsepower
HZ   hertz
ID   identification
MB   megabyte(s)
MHz   megahertz
MP   monitoring point
MW   monitoring well
NA   not applicable, not available
O & M   operations and management
PC   personal computer
PDF   portable document format
PVC   polyvinyl chloride
PW   pump well
RACER   Remedial Action Cost Engineering and Requirements System
R & D   research and development
RI   radius of influence
RPM   rotation per minute
RTF   rich text format
TPH   total petroleum hydrocarbons
U.S. EPA   United States Environmental Protection Agency
VGA   video graphics array
VW   vent well

Part I. Introduction

1.0 Introduction

Bioventing is the process of aerating soils to stimulate in situ biological activity and promote bioremediation. Bioventing typically is applied in situ to the vadose zone and is applicable to any chemical that can be aerobically biodegraded, but to date has been implemented primarily at petroleum-contaminated sites. Through the efforts of the U.S. Air Force Bioventing Initiative and the U.S. Environmental Protection Agency Bioremediation Field Initiative, bioventing has been implemented at more than 150 sites and has emerged as one of the most cost-effective and efficient technologies currently available for vadose zone remediation of petroleum-contaminated sites. As part of the aforementioned effort, Andrea Leeson and Robert Hinchee at Battelle Memorial Institute prepared *Principles and Practices of Bioventing* (two volumes) for guidance to bioventing activities.

During the preparation of *Principles and Practices of Bioventing*, an internally sponsored research and development project had been started at Battelle to build a Bioventing Design Tool to accompany the document. Microsoft Excel spreadsheet program was selected to build the BVDT. The capability of Excel's Visual Basic Applications is the primary reason of this choice. With many existing features and functions of Excel, we were able to construct tables and charts to collect field data and conduct data analyses. Considering the users who have minimal experience with the Excel program, we have built many macros, buttons, menus, charts, and functions to make the BVDT easier to use.

This version BVDT (version 1.0) is the first public release. It contains BVDT, Bioventing Database, BVDT Help File, and User's Guide in Acrobat portable document format (PDF). The entire package can be installed by the Setup program from 3.5" floppy disks.

During the development of the BVDT, we received financial support from U.S. Air Force Environics Directorate to author a User's Guide and further improve the BVDT. This support is highly appreciated.

This User's Guide is composed of six parts and 13 chapters, covering basic techniques and special instructions on using Microsoft Excel and BVDT programs. They are:

Part I
- 1.0   Introduction
- 2.0   Overview of the BVDT Program

Part II
- 3.0   Project Information

Part III
- 4.0   Initial Data Collection
- 5.0   In Situ Respiration Test
- 6.0   Permeability and Radius of Influence

Chapters 3 to 11 correspond to a primary data collection and analysis operation in the bioventing process. Within these chapters, the background information of the section is presented first, and then detailed tutorial instructions and tips are followed. Chapter 12 presents two databases related with bioventing activities collected by Battelle in recent years:

Both databases can be modified by the user to keep them up to date.

Figure 1.1 illustrates the hierarchial diagram of sections and subsections within the BVDT. The numerical number in the parenthesis refers to the section number of the User's Guide.

Bioventing Design Tool

- Site Characterization
  - Initial Depths to GW and Free Product (4.1)
  - Soil Gas Survey (4.2)
  - In Situ Respiration Test (5.0)
    - Initial Soil Gas Readings (5.2.1)
    - Data Analysis (5.2.2)
    - Biodegradation Rate Calc. (5.2.3)
      - Oxygen Density (5.2.3)
      - Soil Bulk Density (5.2)
  - Permeability and Radius of Influence (6.0)
    - Dynamic Method (6.2.1)
    - Steady-State Method (6.2.2)
    - Radius of Influence (6.2.3)
  - Unit Conversion (3.5)
- System Design
  - Blower Design (7.0)
  - Vent Well Spacing (8.1)
  - Soil gas Monitoring Point Spacing (9.2)
  - Installations (9.0)
    - Vent Well Information (9.2.1)
    - Monitoring Point Information (9.2.2)
    - Installation Summary (9.2.3)
    - Initial Depths to GW and Free Product (9.2.4)
  - Unit Conversion (3.5)
- Process Monitoring
  - Soil Gas Monitoring (10.0)
  - Periodic In Situ Respiration Test (11.0)
- Project Information
  - Site Information (3.2)
  - Project Notes (3.3)
  - Summary (3.4)
  - Unit Conversion (3.5)
- Database
  - Case Study (12.1)
    - Open An Existing Bioventing Site (12.1.1)
    - Modify An Existing Bioventing Site (12.1.2)
    - Add A New Bioventing Site (12.1.3)
  - Equipment Information (12.2)
    - Search By Equipment Item (12.2.1)
    - Search By Main Category (12.2.2)
    - Search By Sub Category (12.2.3)
    - Search By Vendor (12.2.4)
    - Update Equipment Item (12.2.5)
    - Update Vendor (12.2.6)
    - Update Main Category (12.2.7)
    - Update Sub Category (12.2.7)
- Quit

Figure 1.1   Structure of Bioventing Design Tool.

The following is a list of menus and their submenus in the BVDT.

BVDT Menu System

File
> Save
> Save As ..
> Print Area
> Print PreView
> Print ...
> Exit

Goto
> Main
>
> ......
>
> Project Information
>> Site Information
>> Project Notes
>> Data Summary
>> Unit Conversion
>
> Site Characterization
>> Initial Depths to GW/Free Product
>> Soil Gas Survey
>> In Situ Respiration Test
>> Soil Gas Permeability and Radius of Influence
>> Unit Conversion
>
> System Design
>> Flow Rate Calculation
>> Blower Selection
>> Well Spacing Calculation
>> Installations
>> Spacing for Monitoring Points
>> Unit Conversion
>
> Process Monitoring
>> Soil Gas Monitoring
>> Periodic In Situ Respiration Test
>
> ......
> Unit Conversion
>
>
> ......
> Database

Print
> Project Information
>> Site Information
>> Project Notes

Data Summary

Site Characterization
Initial Depths to GW/Free Product
Soil Gas Survey
......
In Situ Respiration Test
Biodegradation Rate
Initial Soil Gas Readings
......
Permeability Test: Dynamic Method
Permeability Test: Steady-state Method

System Design
Flow Rate Calculation
Blower Selection
Well Spacnig Calculation
Spacing for Monitoring Points
......
Installations: Vent Well Informations
Installations: Monitoring Points
Installations: Installatioin Summary Table
Installations: Initial Depths to GW/FP

Process Monitoring
Soil Gas Monitoring
Periodic In Situ Respiration Test

Export
Project Information
Site Information

Site Characterization
Initial Depths to GW/Free Product
Soil Gas Survey
......
In Situ Respiration Test
Biodegradation Rate
Initial Soil Gas Readings
......
Soil Gas Permeability: Dynamic Method
Soil Gas Permeability: Steady-state Method
Radius of Influence

System Design
Flow Rate Calculation
Blower Selection
Well Spacnig Calculation

Spacing for <u>M</u>onitor _g Points

......

Installations: Installatioin <u>S</u>ummary Table
Installations: Initial <u>D</u>epths to GW/FP

<u>P</u>rocess Monitoring
    Soil <u>G</u>as Monitoring
    Periodic In Situ <u>R</u>espiration Test

<u>E</u>dit

<u>C</u>opy
<u>P</u>aste
Paste <u>S</u>pecial...

<u>H</u>elp

<u>B</u>VDT Help
Bug <u>R</u>eport
A<u>b</u>out BVDT

......

Microsoft Excel <u>H</u>elp Topics
Answer <u>W</u>izard

<u>A</u>bout Microsoft Excel

If you have any questions or suggestions on the BVDT program, please refer to A<u>b</u>out BVDT under the <u>H</u>elp menu, and contact us with it's version number and details about the problem.

2.0 Overview of the BVDT Program

2.1 Installing and Starting Bioventing Design Tool

2.1.1 Installing Bioventing Design Tool

The Bioventing Design Tool can be used on any IBM compatible computers running either Windows 3.1 or Windows 95, and Microsoft Excel version 5.0 or later. The minimum hardware requirement is 4 megabytes hard-disk space, regular VGA color monitor, mouse, and printer.

The BVDT is installed by a Setup program, which copies necessary files to your computer in a user-specified directory.

Step 1   Make sure you have Windows 3.1 or Windows 95 and Microsoft Excel version 5.0 or later installed on your computer.

Step 2   Quit all applications on the computer. Insert 'Disk 1' of BVDT installation disks to the floppy drive, either A: or B:. If you are installing from a network shared directory or a file server, connect to that directory.

Step 3   For Windows 3.1 users: In Program Manager, from the File menu, choose Run.... In the Command Line dialog box, type **a:\setup**. If you are installing from a network drive, type the full path of that directory with the Setup file name.

For Windows 95 users: Click the **Start** button, choose Run... menu. In the Run dialog box, type **a:\setup**. If you are installing from a network drive, type the full path of that directory with the Setup file name.

Step 4   When Setup starts, follow the instruction on the screen (Figure 2.1.1.1). If you have some applications running, you might get the Setup error message as shown in Figure 2.1.1.2. Click the **Cancel** button, quit all applications and then restart from Step 3.

Step 5   Verify the destination directory of your files (Figure 2.1.1.3). The default directory name is c:\BVDT. If it does not exist, the Setup program will create the directory. If you want to change the directory, click the **Change Directory** button. You can make changes in the Change Directory dialog box (Figure 2.1.1.4).

Step 6   Click the large square button with a computer on it (Figure 2.1.1.3) to continue the Setup process. The Setup Status message box (Figure 2.1.1.5) shows up. During the process, you will be asked to insert 'Disk 2' and 'Disk 3' into drive A: or B:. At the end of the Setup, you will see the Setup Completion message box (Figure 2.1.1.6).
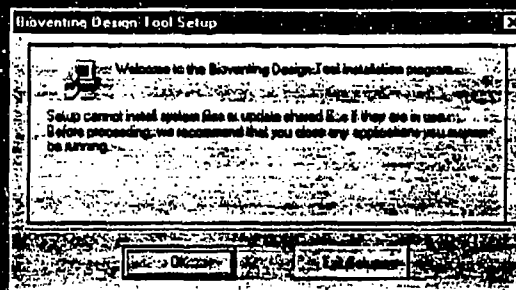
Figure   2.1.1.1   The BVDT Setup Program
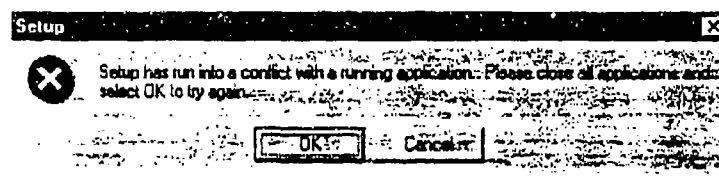
Figure 2.1.1.2   Setup Error Message Box
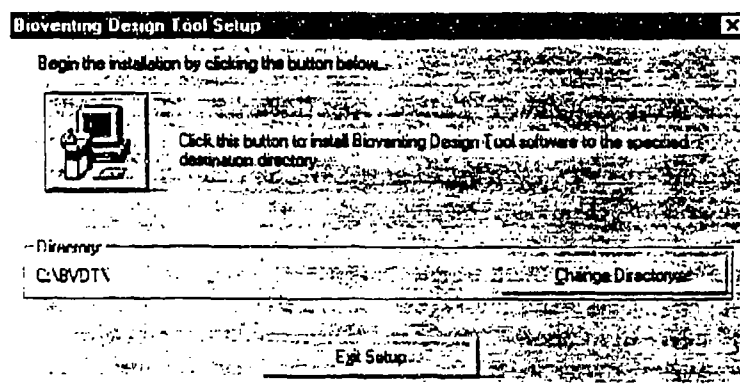
Figure 2.1.1.3   Confirm Destination Directory During Setup
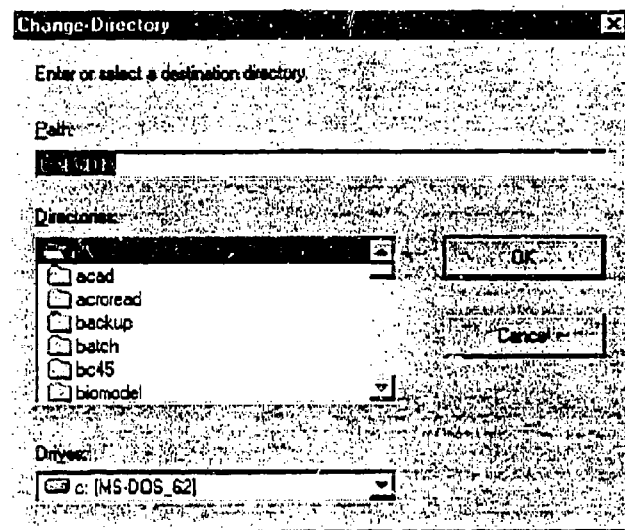
Figure 2.1.1.4   Change Destination Directory During Setup
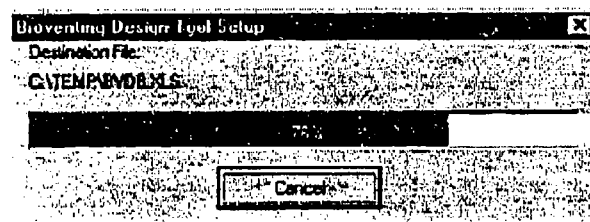
Figure 2.1.1.5   Setup Status Message Box
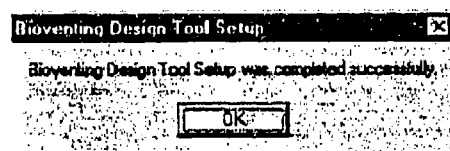
Figure 2.1.1.6   Setup Completion Message Box

2.1.2 Starting Bioventing Design Tool

The Bioventing Design Tool is by nature a spreadsheet file that runs on an Microsoft Excel program (version 5.0 or later). It uses xls as its file extension similar to other Excel data files. The differences between the BVDT and other Excel files are the custom-built menus,

buttons, list boxes, dialog boxes, subroutines, equations, and diagrams in addition to regular data and charts. Because of these custom-built extra features, this BVDT file cannot be converted to be used in other spreadsheet programs, such as Lotus 1-2-3.

To start the BVDT, you have to launch the Microsoft Excel program first. Within Excel, from File menu, choose Open... submenu. The Open dialog box pops up (Figure 2.1.2.1). You can either type c:\temp\bvdt.xls in File name area or browse the file hierarchy to select the bvdt.xls file. After you click the Open button, the BVDT begins. On an Intel 486 PC, it takes a longer time to start the program than on a Pentium PC.
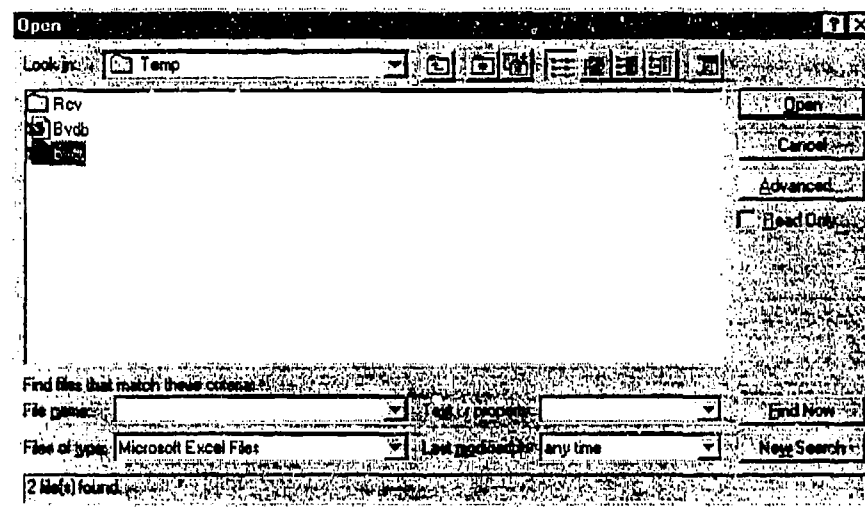
Figure 2.1.2.1   Open the BVDT File

2.2 Terminology

To make our discussion clear in the User's Guide, some terms besides those commonly used in Windows programs are defined in the following paragraphs.

Dialog Box
A dialog box is a pop-up window used to input text, select a check button, or bring up another window. It is usually invoked by a menu, a button, or another dialog box. Figure 2.2.1 is an example of a Save As dialog box.
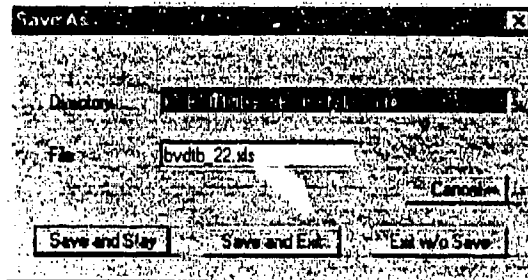
Figure 2.2.1   An Example of a Dialog Box
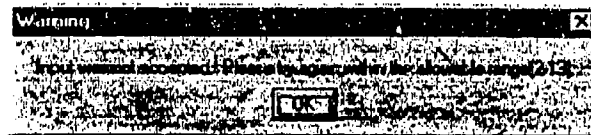
Figure 2.2.2   An Example of an Information Box (Message Box)

Information Box or Message Box

An information box or a message box is a pop-up window to inform the users. Usually no further action is required. The information box can be closed by clicking the OK button. Figure 2.2.2 is an example of the warning information box.

Level and Section

BVDT is constructed in a hierarchy with multiple levels. Each section resides on one level. For example, the BVDT main screen is on the first level; by clicking the Site Characterization button on the main screen, users access the second level; by clicking the In Situ Respiration Test button, users can access another three on the third level: Initial Soil Gas Readings, Data Analysis, and Biodegradation Rate Calculation.

List Box

A list box is another format common to Windows programs. By clicking the arrow on the righthand side of the list box, a list is displayed. Users move the mouse cursor to highlight and make the selection. If there are more selections than the window can display, a vertical scroll bar shows up. Users can select the hidden list by moving the scroll bar. Figure 2.2.3 shows an example of a list box.
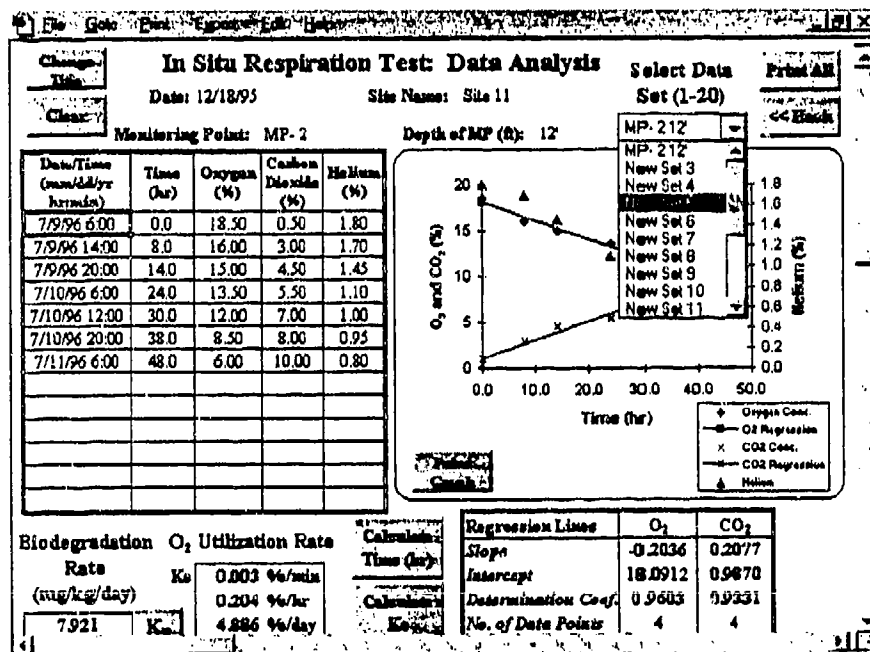
Figure 2.2.3   An Example of a List Box

Page

A page refers to one set of data presented in a work screen. For example, there are several respiration tests conducted at various sites. The BVDT can display only one set of data at a time. By using the list box as shown in Figure 2.2.3, one can select a set of data from the list and display them on the screen. Each set of data contributes to one page of a work screen.

Work Screen

A work screen is a computer monitor display. In a specific work screen, the layout and table format remain the same while the contents of tables can be changed. By using screen dump command (Alt+Print Screen), the work screen can be copied to the computer clipboard and pasted to any Windows program.

2.3 Basic Techniques for Using the Microsoft Excel Program

The Microsoft Excel program has many features and is sometimes difficult to master. One goal of this BVDT is to maximize the capability of Excel by users. They can take advantages of Excel by clicking preprogrammed buttons or menus without in-depth knowledge of Excel. However, we still recommend our users to know some of the basic operations of Excel to be more efficient in using the BVDT program.

2.3.1 Copy and Paste in Excel

To copy the contents of one or more cells, a user needs to highlight the cell(s) by selecting the cell at one corner of the range (a range is composed of a group of cells), holding down the left mouse button, and dragging the mouse over to the opposite corner of the range. Another way of highlighting the range is to select the cell at one corner of the range by holding down the Shift key while moving the arrow key(s) to the opposite corner. After the range is highlighted, use either the Ctrl+c (clicking the c key while holding down the Ctrl key) shortcut key or Copy from the Edit menu to copy the contents of the range to the clipboard of the operating system. Next, select the cell at the corner of the range you want to copy to, and type the Ctrl+v shortcut key or Paste from the Edit menu to copy the contents from the clipboard to the range.

For example, we have a data table defined in the range of B2 to D4 as shown in Figure 2.3.1.1. By highlighting the range we want to copy, we can copy it to the clipboard and then paste it to the range of G9 to I11 (Figure 2.3.1.2).
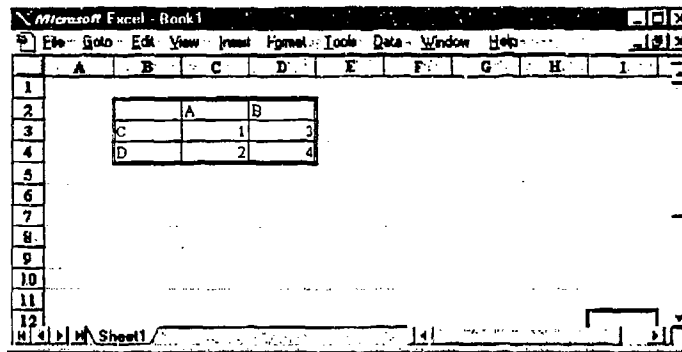
Figure 2.3.1.1   Highlighting and Copying the Range
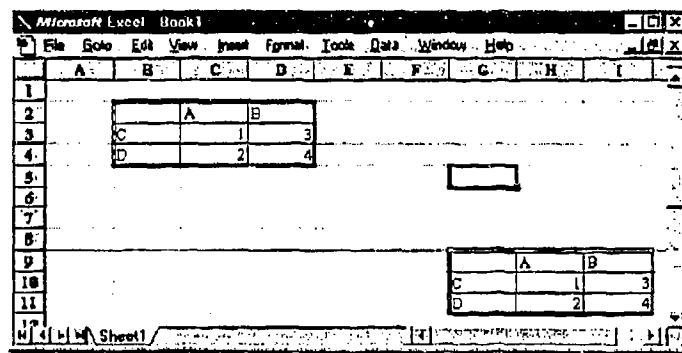
Figure 2.3.1.2   Copy a Table from Range B2..D4 to Range G9..I11
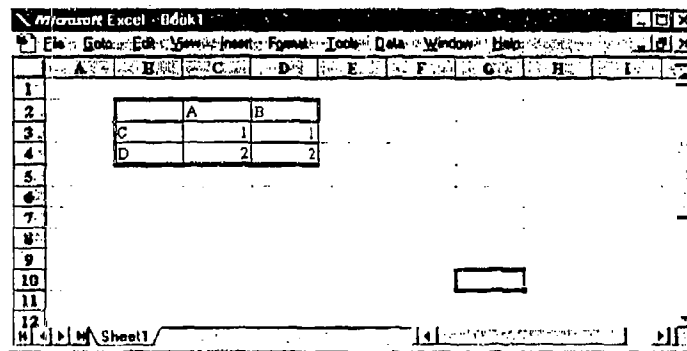
Figure 2.3.1.3   Copy Column C3..C4 to D3..D4
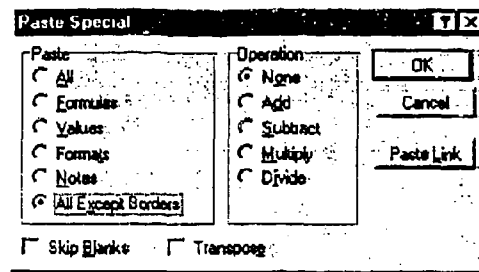
Figure 2.3.1.4   Paste Special Dialog Box

We can copy part of a column to another column in the same table as well. For example, copy range C3..C4 to range D3..D4. From Figure 2.3.1.3 we notice that the cell borders of range C3..C4 are copied to range D3..D4 along with the data. If we intend to copy only the data value to another cell, we can choose Paste Special... from the Edit menu, and check the **All Except Borders** option (Figure 2.3.1.4).   When using the Ctrl+v shortcut key, the default option of **All** is used. However, when using the BVDT, there is no need to worry about the borders being changed. As soon as you enter the section again, the borders will be reformatted. A detailed description is provided in Section 2.4.8.

2.3.2 Print in Excel

For the ease of use of the BVDT program and standardization of tables and charts, the BVDT provides a **Print** button for almost all sections you work on. The printing command associated with the **Print** button prints everything a user sees on the screen except buttons, list boxes, and a few drawing objects.

However, if a user wants to print differently than a standard printout generated by clicking the **Print** button, for example, a chart without a data table, the user needs to

> Highlight the printing area,
> Choose Print Area, Set Print Area from the File menu,
> Select the Print... menu, and
> Click OK on the Print dialog box.

For example, to print a chart of the respiration test, we can select the cells covered by the chart first, then set the highlighted area as a print area, and finally select Print from File menu (Figure 2.3.2.1). The Print dialog box should look like Figure 2.3.2.2. Click OK to print the chart to a printer.

By failing to highlight the cells you want to print and reset the print area, you might not be able to print what you want. The reason is that whenever you click on the **Print** button, the program sets a print area for printing, and this printing area will not be removed or modified until the next Set Print Area command is issued either by assigning a printing area manually or by clicking another **Print** button.
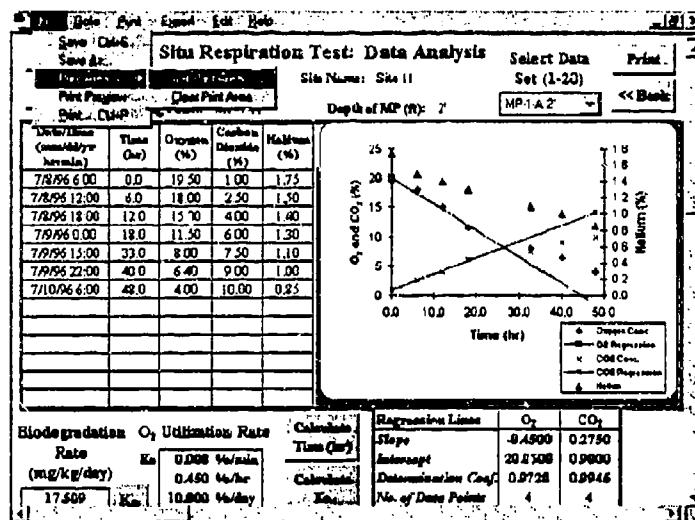
Figure 2.3.2.1   Select Part of an Area to Print
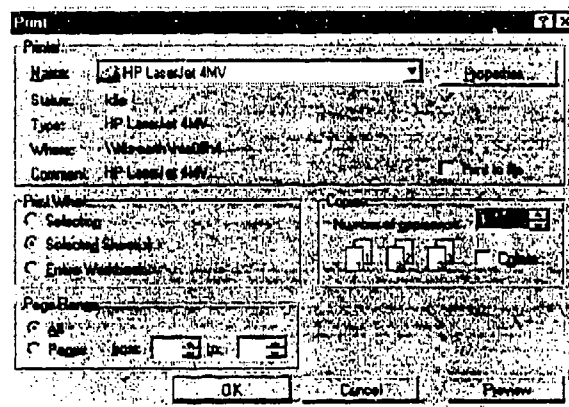
Figure 2.3.2.2   Print Dialog Box

2.3.3 Copy an Excel Table to a Word Document

There is a **Print** button in almost all work screens of the BVDT. Users can produce a printout easily by clicking this button. To include this printout in a project report, one can do the following:

a. Highlight the area you want to include in the report by selecting the corner of the area by holding down the left mouse button while dragging the mouse to the opposite corner. (Figure 2.3.3.1)

Figure 2.3.3.1   Highlight the Area to be Copied

b. Select Copy from the Edit menu in Excel.

c. In a word processing program, such as Microsoft Word, select Paste Special ... from the Edit menu.

d. In the **Paste Special** dialog box, as shown in Figure 2.3.3.2, check "Paste, As: Microsoft Excel Worksheet Object" or "Picture", and hit the **OK** button. The result is shown in Figure 2.3.3.3.
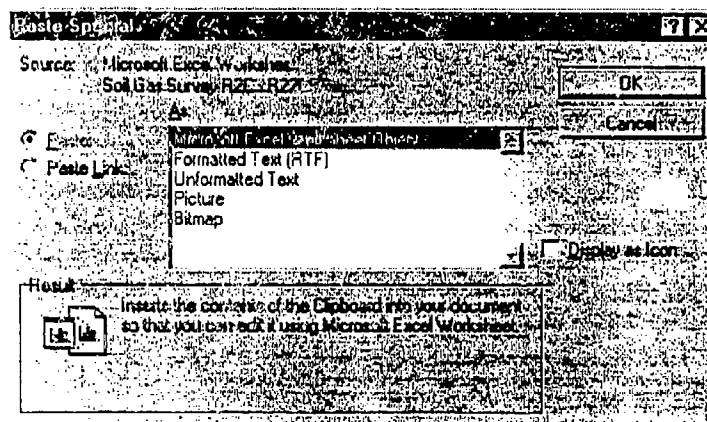
Figure 2.3.3.2   Paste Special Dialog Box

Soil Gas Monitoring

Site Name: Site 11

Operator(s): M. Smith   Date and Time: 4/20/96 12:30

Monitoring Point ID	Depth (ft)	Readings			Pump Pressure (in Hg)	Comments
		O_2 (%)	CO_2 (%)	TPH (ppm)		
mp-1	3.0	2.00	7.50	4500		
mp-1	6.0	2.50	6.50	3200		
mp-1	8.0	3.00	5.00	1200		
mp-1	10.0	NM	NM	NM		Water was encountered at this depth
mp-2	3.0	0.50	6.50	2200		
mp-2	6.0	3.00	6.50	1200		
mp-2	10.0	2.50	6.50	1180		
mp-3	4.0	1.00	10.00	20000		
mp-3	8.0	2.00	9.50	10000		
mp-3	10.0	3.00	9.00	10000		
mp-4	4.0	0.50	8.00	9500		
mp-4	8.0	1.00	8.50	8000		

Figure 2.3.3.3   An MS Excel Worksheet Pasted to an MS Word Document

e. By clicking the pasted object, you can change the size of it by dragging one corner of the object to fit the layout of your document.

The reason not to select Formatted Text (RTF, rich text format) is that sometimes such pasting cannot keep the original text format. For example, the Site Name in Figure 2.3.3.3 might be wrapped up in two lines because of a width limitation in a table cell.

2.4 Common Features of BVDT

During the development of the Bioventing Design Tool, we attempted to make the program easy to use and understand, regardless of the experience level of the user. A primary feature of the Windows program is the mouse point-and-click feature. The BVDT continues this feature by having many special functions assigned to buttons, as long as space on a computer screen is available in addition to tables and charts. When the screen space is limited, we assign the command to a menu. This is one of many features in the program to help our users do their job faster and easier.

2.4.1 Print Button

By default, when a user selects the Print menu in Excel, the program will print either the selected printing area or the area on the worksheet with active cells (the cells covered with data, equations, and charts). The **Print** button is designed to perform the following tasks for a user: assigning a range of cells for printing, selecting the orientation of the paper (either landscape or portrait) depending on the layout of the chart and data tables, and sending one copy of the print job to a printer.

In a Windows program, you can select a printer either from the *Printer Setup* of a program, the *Printer Manager* of Program Manager in Windows 3.1, or Printers from My Computer in Windows 95. It is recommended to check the default printer before sending any print jobs from the BVDT, because the program sends the job to the default printer.

If a user wants to print only the chart, a **Print Graph** button is also provided. In order to print a chart or a table differently than the standard output using the **Print** button, please refer to Section 2.3.2.

2.4.2 User Input

The BVDT is designed to decrease redundant input as much as possible. For example, under the assumption that all data from one particular site is stored in one BVDT file, the Site Name becomes a constant throughout the program. The only place where the site name needs to be input is in the Site Information section. In all other sections, the site name is automatically provided. However, some information might change even on a project for one specific site, for example the operators. The user must input such information at each section.

To distinguish these two types of information, an underline is provided to indicate the requirement of data input. This is shown clearly in Figure 2.4.2.1. This section is for calculating soil gas permeability using the steady-state method. The Site Name is shown without an underline, which indicates it does not require input. As a matter of fact, the cell with this information is locked to prevent accidental deletion. The Date area has an underline. Therefore, user input is required, such as 3/28/96. Because this underline serves only as a reminder to the user, the underline will not be shown in the printout.

Soil Gas Permeability

Site Name: Site 11   Date: 3/28/96

Item	Symbol	Value	Unit
Volumetric Flow Rate from the Vent Well	Q	19821.79	cm^3/s
Viscosity of Air (1.80x10⁻⁰⁴ g/cm-s at 64.4 °F (18 °C))	u	1.80E-04	g/cm-s
Ambient pressure (at sea level 1.013 x 106 g/cm-s²)	P_{am}	9.46E+05	$g/cm\text{-}s^2$
Absolute Pressure at the Vent Well	P_w	9.96E+05	$g/cm\text{-}s^2$
Diameter of Vent Well / 2	R_w	2.54	cm
Length of Screened Interval	H	1233.60	cm
Radius of Influence-Previously determined	R_i	3048.00	cm
Soil Gas Permeability (for Vacuum Well)	k	6.81	darcy
Soil Gas Permeability (for Air Injection Well)	k	6.47	darcy

R_i (Previously Calculated): 138.30 ft   =   4215.46 cm   << Back   Print

Figure 2.4.2.1   Required and Not Required User Input

There is another protection available in the program. If an input to a cell is not desirable, such as a cell with an item name, a symbol name, or a constant as shown in Figure 2.4.2.1, the cell is locked. The users are allowed only to input data into the unlocked cells. If the cells contain information calculated from other cells and no user input is necessary, the cells are filled with a light yellow background color. Soil gas permeability at the bottom of Figure 2.4.2.1 is an example of this.

2.4.3 Clear Button

A user can delete or clear the contents of cells by highlighting the cells and clicking the **Delete** key on the keyboard. When a user wants to delete all input data in a section, the **Clear** button becomes useful. However, if there are multiple pages of information in one particular section, for example, there are 12 pages in Project Notes, the **Clear** button can delete only the contents of one page at a time. In other words, the **Clear** button clears only the cell contents currently shown on the screen.

2.4.4 Change Title Button

The **Change Title** button provides the flexibility for a user to choose a suitable title for a data analysis printout. By clicking the **Change Title** button, you will be prompted by a dialog box as shown in Figure 2.4.4.1, which has the current title highlighted in the input area. You can change the title by typing a new title and clicking the OK button. The text font and size are not changeable by a user. The BVDT program uses Times New Roman font.
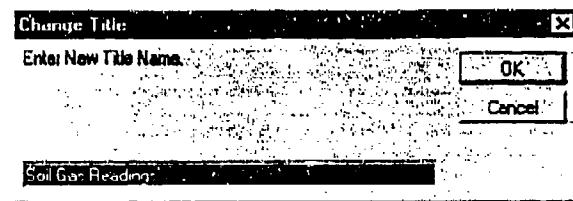
Figure 2.4.4.1   Change Title Dialog Box

2.4.5 Save Button

It is recommended to save the program file frequently. Using the Save or Save As...
submenus from the File menu is one way of saving your data file. When you click the **Save**
button in a regular session, the BVDT file will be saved in its same name, which is equivalent to
Save from the File menu. To save the file as a different name, please refer to Section 2.4.6.

2.4.6 Quit Button

The **Quit** button in the main window can be used for changing the file name, saving the
file, and quitting the Excel program. When the user clicks the **Quit** button, the Save As dialog
box appears (Figure 2.4.6.1). As a default, the current directory and file name will appear in the
Directory and File edit boxes. If a user wants to save the file in a different directory or drive, or
save as a different file name, one needs to input this information. It should be pointed out that the
first three letters in the Directory edit box have to be in the sequence of drive name (A to Z, or a
to z), a colon, and a slash. For example, c:\ or C:\ are all correct. If either one of these letters is
not correct, a warning message shows up and the user is prompted to re-input the directory
information.
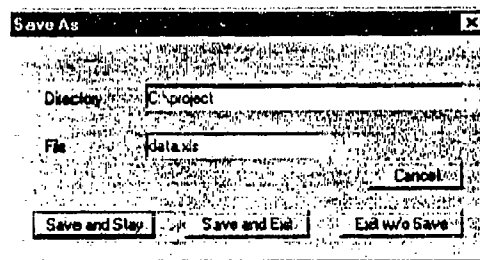
Figure 2.4.6.1   Save As Dialog Box

All four buttons in the Save As dialog box are self-explanatory. The **Save and Stay**
button can be used to change the file name. If the file name already exists, a warning dialog box
shows up (Figure 2.4.6.2). Click **Yes** button if you still want to save the file with an existing file
name and overwrite the old file.

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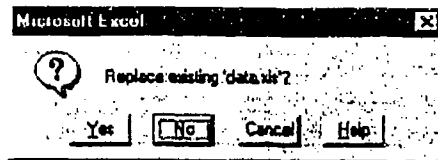
Figure 2.4.6.2   Confirmation for Saving an Existing File

2.4.7 Export Menu

The **Export Data** button performs a task of saving the tabular data into a comma space delimited ASCII file. When click the **Export Data** button, a Data Export dialog box appears (Figure 2.4.7.1). After typing the correct directory and file name, click the **OK** button to proceed with the export.

Figure 2.4.7.1   Data Export Dialog Box

Figure 2.4.7.2   Vent Well Spacing Calculation Section

For example, if the user wants to export the data in Vent Well Spacing Calculation section as shown in Figure 2.4.7.2, the exported data would look like those in Figure 2.4.7.3. If the cell is blank, the space for that cell is eliminated in the CSV (comma-separated values) file. If the text is long and contains blank spaces, the text will be exported by a pair of quotation marks surrounding the text string.

Site Name:,Site 11,,Date:,35066

,Case 1,Case 2,Case 3,Case 4
Flow Rate (cfm),20,20,,
Oxygen Utilization Rate (%/day),4,4,,
Air-filled Porosity ,0.4,0.3,,
Aerated   Thickness (ft),20,20,,
Radius of   Influence (ft),67.5,85.4,,
Empirical Radius of Influence (ft),138.3,,,
Required Radius of Influence (ft),70,,,
Well Spacing (ft),100,,,

Figure 2.4.7.3   Exported Well Spacing Section Data in CSV Format

2.4.8 Reformatting Borders

As discussed in Section 2.3.1, if we use the Ctrl+v shortcut key to copy and paste one set of data, the borders of original cells will be pasted as well. To reformat these borders, a user needs to go one level up from the current section, and come back to the section again. At that time, the borders will be reformatted by the program automatically. An alternative is to use the Paste Special menu and select the All Except Borders option (Figure 2.3.1.4) so that the borders will not be pasted to the new location.

2.4.9 Print Work Screens

On each work screen, there are usually several buttons, list boxes, and texts to help the computation tasks. Considering many printouts are the direct print from the layout of the work screen, these buttons, list boxes, and texts are not printable when a user hits the **Print** button. To make a hard copy of these work screens as we do in this User's Guide, a user needs to hold down the Alt key while pressing the Print Screen key to copy the current window on the screen to the clipboard, and then paste it in a Windows program, such as Microsoft Word, to print it out.

2.4.10 Change the Name of an Item in a List Box

In some sections, the BVDT provides multiple pages for one work screen, such as the one shown in Figure 2.4.10.1, where a total of 20 depths of various monitoring points can be recorded. At the beginning of the session, the names in Select Data Set might be called MP-X Y, where X

stands for the monitoring point and Y stands for the depth of the monitoring point X. After a user inputs the site-specific name to the Monitoring Point and the depth in Depth of M.P. (ft), the name in the Select Data Set will be changed by selecting another data set and coming back to the session. The newly named MP-X Y will be used from then on to identify the respiration test data for that particular location.
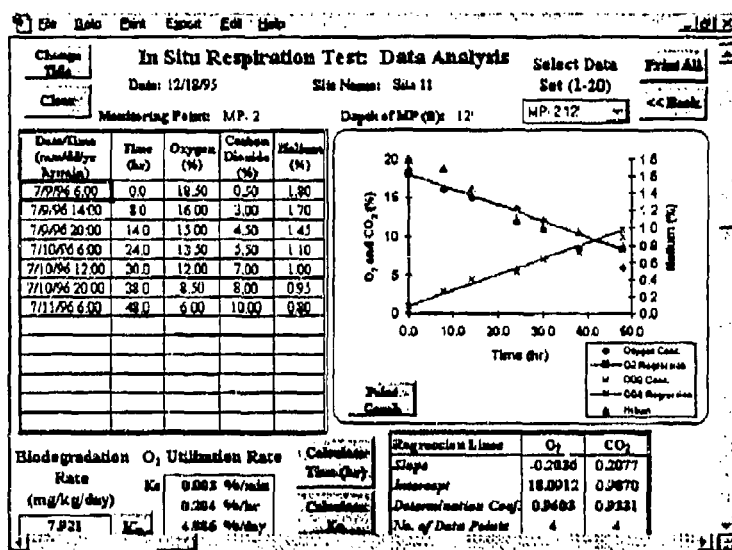
Figure 2.4.10.1 List Box in a Work Screen

2.4.11 Back and Main Buttons

Two buttons, Back and Main, help users move from one work screen to another. The Back button moves one level up, and the Main button moves back to the start screen.

2.4.12 Moving Around Cells

There are several ways to move around cells in Excel: tab key, arrow keys, and with a mouse. Because the BVDT is developed on the Excel program, that limits our control on a tab key. It usually moves toward the next unlocked cell on the same row until the end of the row, and then moves to the unlocked cell on the next row. This causes unintentional shifting of the work screen toward the right. If this happens, the quickest way to move back to the intended work screen is to scroll to the upper left of the worksheet; that is, the vertical scroll bar goes to the top and the horizontal scroll bar goes to the left. Using the Goto menu also helps to go back to the right screen. We recommend using either the arrow key or the mouse instead of the tab key to move around cells in the work screen.

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2.4.13 Goto and Print Menus

In the BVDT, we purposely display only six menus: File, Goto, Print, Export, Edit, and Help. Among these menus, Goto, Print and Export, are custom menus. Each of them has submenus. Every submenu corresponds to a section of the BVDT. While working at one work screen, users can jump to another section without following the section hierarchy, which usually requires the user to go to the top level and then go down to the desired level. The Goto and Print menus work similarly. For example, if the current work screen is Project Notes, by selecting the Goto menu from Site Characterization and its submenu Soil Gas Permeability and Radius of Influence, users can jump to the Soil Gas Permeability and Radius of Influence section immediately (Figure 2.4.13.1). If it is in the Print menu, one can print the Soil Gas Permeability and Radius of Influence: Dynamic Method data while working in the Project Notes section.
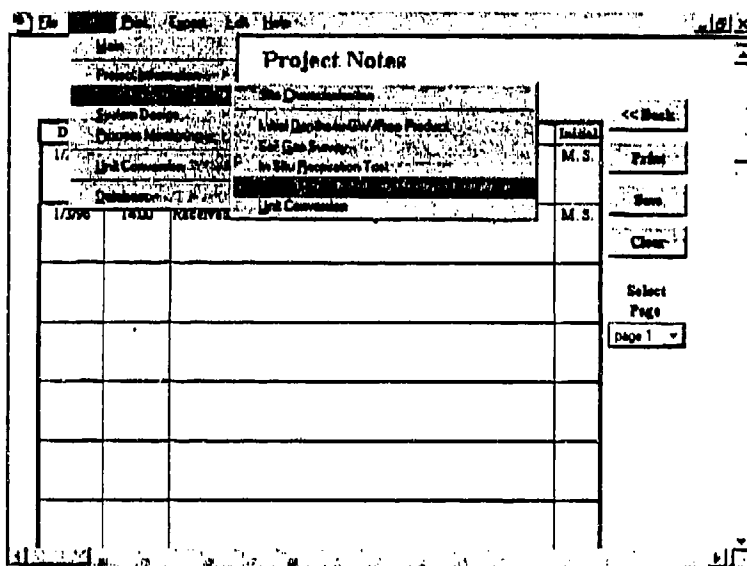
Figure 2.4.13.1   Using Goto Menu

2.4.14 Help Menu

The entire content of this User's Guide has been compiled to be a help file to provide on-line help. By choosing BVDT Help from the Help menu, users can start the Windows help search engine. It should be noted that Windows 3.1 has a different help search engine than Windows 95. Windows 95 has an extra function of compiling a word list from the help file for users to search. We discuss only the Windows 95 help search engine in this Guide.

The Help Topics window of Windows 95 is shown in Figure 2.4.14.1. There are two ways of searching the topics: Index and Find. One can choose one of them by clicking the tab with that name on it. Within Help through the Index, one can find a topic by typing the first few letters in the blank area. In addition to the section titles in the User's Guide, some key terms and names are indexed. The index is listed alphabetically. As soon as an index entry matches what one types, the Display button becomes highlighted. Clicking the Display button brings up another

window to show the content of that topic. Some help topics contain green underlined text called hyper text. You can click on the hyper text to see the definition of the term.

The standard Windows 95 Help search engine can make a list of words used in the help file. It helps users to find a topic by providing a few words. Because this list of words is not included within any help files, Windows 95 search engine uses Find Setup Wizard (Figure 2.4.14.2) to compile it as soon as one clicks the Find tab in Help Topics window. The user follows the instructions on the screen to create a list of words. The product of this process is a *.FTS file. It needs only to be created once. After the list of words is built, the user can type a few words to find the topic related with those words (Figure 2.4.14.3).
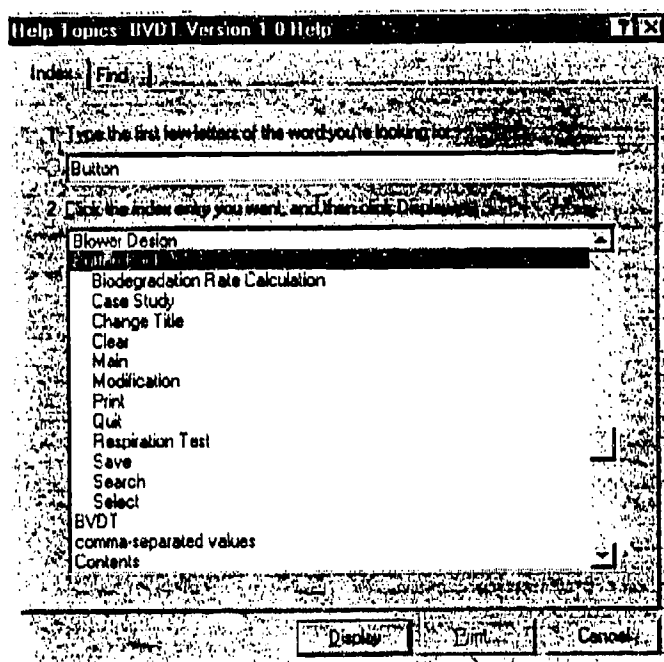
Figure 2.4.14.1   Help Window
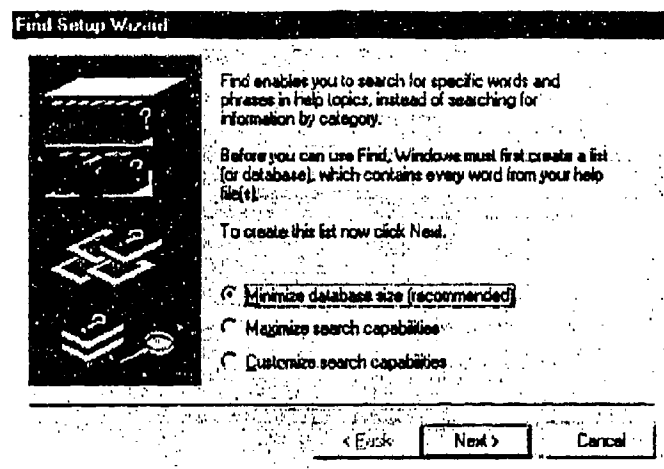
Figure 2.4.14.2   Find Setup Wizard in Windows Help
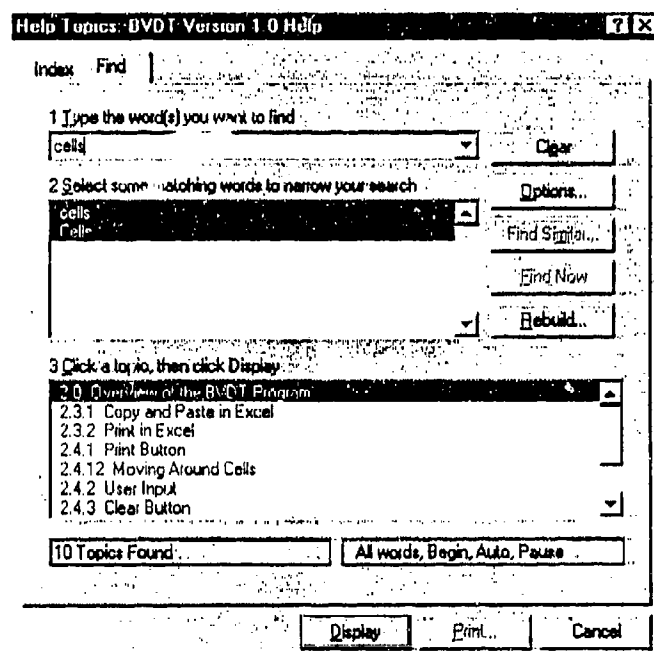
Figure 2.4.14.3   Find a Topic Containing a Word or a Phrase

2.4.15 Bug Report

There is a submenu Bug Report under the Help menu. Whenever a bug is discovered, users can fill out the report and either fax or e-mail it to the address shown at the bottom. Figure 2.4.15.1 shows the work screen for the Bug Report.

Figure 2.4.15.1   Bug Report Work Screen.

Part II. Project Information

3.0 Project Information

3.1 Introduction

The Bioventing Design Tool can be used not only for collecting and analyzing field data, but for keeping project activity notes electronically. The general site information and point of contact information are included in the **Site Information** section. Major events that happened during the project period can be typed into the **Project Notes** section. The overall contamination information of the site can be inputted in the Data Summary section. The last section of this chapter discusses the usage of a utility program to convert commonly used units.

3.2 Site Information

The Site Information is composed of three parts: the site location and contamination information, the staff work on the project, and the site point of contact. The site name inputted in this work screen is linked to all places in the BVDT where the site name is required. This is the only place a user can modify the site name.

Figure 3.2.1   Site Information Work Screen

3.3 Project Notes

The **Project Notes** table is composed of four columns labeled Date, Time, Notes, and Initial (Figure 3.3.1). Each page can accommodate up to 14 entries. Because the table is longer than the regular computer screen height, the user has to use the up vertical scroll bar to reach the lower part of the table. A total of 10 pages are available. The user can flip to another page by selecting the page number from the **Select Page** list box. The page number is indicated at the bottom of each printout (Figure 3.3.3).

Figure 3.3.1   Project Notes Work Screen

Tips and Tricks

Microsoft Excel has a limitation of 256 characters in each cell. Because each blank area in **Project Notes** is a cell, it is under the same restriction. If a long text is typed, a warning message will show up as in Figure 3.3.2. The simple solution is to continue in the next entry of the Notes.
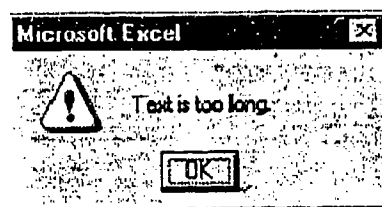
Figure 3.3.2   Text Too Long Message Box

Project Notes

Site Name: USA AFB, Site 123

Operators: M. Smith

Date	Time	Notes	Initial
1/2/96	13:00	Called site POC.	M. S.
1/3/96	14:00	Received site characterization report from ABC Corp.	M. S.

page   1

Figure 3.3.3   Printout of Project Notes

3.4 Project Data Summary

The Project Data Summary table is designed to summarize all key information of one particular bioventing project before and after the bioventing process. This table provides the following categories of information to readers: Contamination Type, Depth of Groundwater and Free Product, Physical Characterization, Chemical Characterization, Microbial Characterization, Contamination before and after bioventing process, Vent Wells, Monitoring Points, Blower Type and Configuration, and Comments.

Figure 3.4.1 shows the work screen of the Data Summary. The up and down arrow buttons on the table help to move to the upper and lower part of the table. Because there is only one entry space for each data, but usually more than one data is collected from various monitoring points and samples at the site, BVDT users need to select the representative data for this table. For the same reason, all the data except site name needs to be entered manually by users rather than linked automatically to the other tables in the BVDT.

This table was designed to be the same as the table used for Bioventing Case Study in Part V Database, users can easily add this site's data into the database.

Figure 3.4.1   Work Screen of Project Data Summary

3.5 Unit Conversion

Bioremediation technology integrates many disciplines, and a variety of terminology and units are used among professionals. Some units widely used in the field activities are different from those used in numerical analyses. In this section, the BVDT provides a convenient tool to convert commonly used units for the users.

Figure 3.5.1 shows the Unit Conversion work screen. There are three list boxes, one data input window, and one data output window. The first list box is called Dimension. By clicking the arrow of the list box, users can select one of the following dimensions in alphabetical order: concentration, flow, length, mass, permeability, pressure, temperature, viscosity, and volume.

Two other list boxes are Convert From and To, which list the units for the dimension selected by users. These units are also listed in alphabetical order. The number of units available for each dimension varies. However, as soon as the dimension is chosen, the default unit is the first one in the list.

To use this Unit Conversion program (Figure 3.5.2), users select a dimension first; then select appropriate units in both Convert From and To list boxes; next, users type in the value to be converted in the window below Convert From, and the converted value is shown immediately in the yellow-highlighted window. For example, if we want to convert the pressure from inches of mercury to Pascal, we select Pressure from Dimension list box, in of Hg from Convert From list box, kg/ms^2 (Pa) from To list box, and type 10 in input window, we obtain 33862 Pascal as the result.
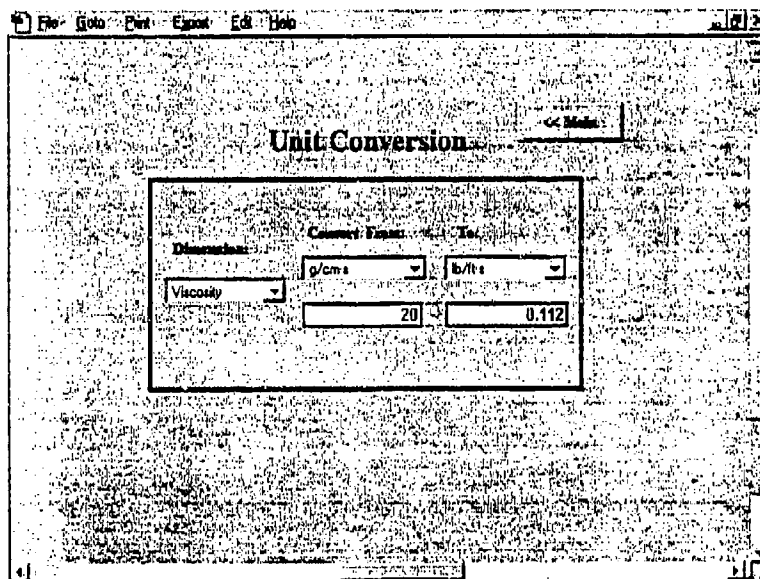
Figure 3.5.1   Unit Conversion Work Screen
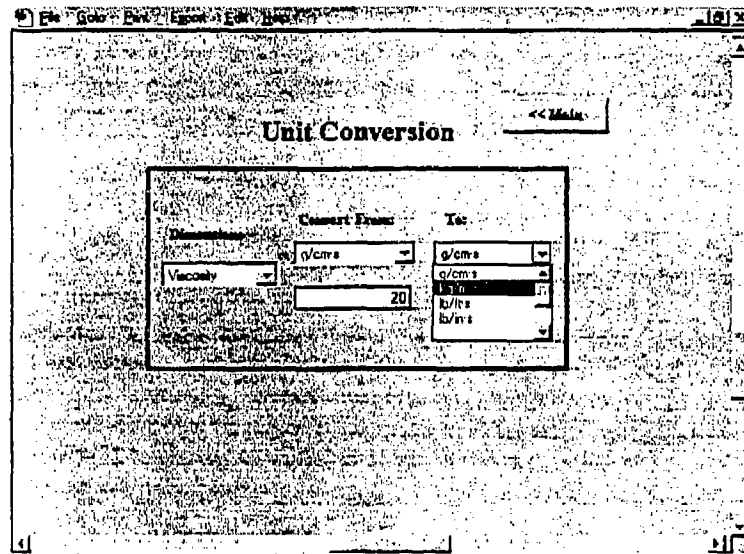
Figure 3.5.2　An Example of Using Unit Conversion

Part III. Site Characterization

4.0 Initial Data Collection

The first step in site characterization is to collect initial data of the site to help determine where to and how to conduct the pilot test. One set of data is the depths of groundwater and free product at monitoring wells, and another set of data is the initial soil gas readings at all monitoring points before any bioventing activities. The details of collecting these two sets of data are described in the following sections.

4.1 Initial Depths to Groundwater and Free Product

The initial depths to groundwater and free product are measured through any existing wells on site. This set of data is important to the selection of potential bioventing site and comparison of initial and final contamination readings. The table of initial depths is shown in Figure 4.1.1. It is primarily composed of five columns: Well Identification, Well Type, Depth to Free Product, Depth to Groundwater and Product Thickness. It is assumed that the depth is measured from top of casing (TOC) of the well to the surface of free product or groundwater. The elevation of free product surface and groundwater surface is not needed. Since we are only interested in the free product thickness, which is the difference between depths of groundwater and free product.

By entering the depths to free product and groundwater, the thickness of free product is calculated automatically. If there is no free product in the well, the user leaves a blank in the Depth to Free Product column, so that the Product Thickness is labeled as NA (not available).

Because this table can be accessed from both **Site Characterization** and **Installations**, users can move to these two section directly.

Initial Depths to Groundwater and Free Product

Site Name: Site 11   Date: 1/1/96
Operators: L King

Well Identification	Well Type	Depth to Free Product (ft)	Depth to Groundwater (ft)	Free Product Thickness (ft)
MW-1	monitoring well	3.00	3.12	.12
MW-2A	monitoring well	2.89	3.00	.11
MW-2B	monitoring well	3.00	3.20	.2
MW-3	monitoring well	3.50	4.00	.5
MW-5	monitoring well		2.33	NA
MW-6	monitoring well	3.00		3

Figure 4.1.1 Work Screen of Initial Depths to Groundwater and Free Product

4.2 Soil Gas Survey

Soil Gas Survey is part of site characterization before any bioventing activities. It samples soil gas from various survey points at existing wells, detects its concentrations of oxygen, carbon dioxide, and total petroleum hydrocarbons to determine whether oxygen-limited conditions exist. The Survey also helps to locate the contamination distribution area and select positions for installing vent wells and soil gas monitoring points. It is a good indication of active microbial activities if the soil gas oxygen concentration is below 5% but carbon dioxide concentration is above 10%.

The soil gas survey should be conducted before installing any vent wells and monitoring points for the pilot test. The soil gas is extracted through a probe from the soil to a Tedlar sample bag using a vacuum sampling pump. Then a O_2/CO_2 analyzer and a hydrocarbon analyzer are used to take soil sample readings.

The soil gas survey table is shown in Figure 4.2.1. It has seven columns: Soil Gas Survey Point, Depth, O_2, CO_2, TPH, Pump Pressure and Comments. Although the table is similar to that in the Soil Gas Monitoring Section, this table does not have multiple pages for data entry.

<< Back | Change Title

Print | Clear

Soil Gas Survey Data

Site Name: Site 11

Operator(s): _____   Date: _____

Soil Gas Survey Point	Depth (ft)	Readings			Pump Pressure (in Hg)	Comments
		O₂ (%)	CO₂ (%)	TPH (ppm)		

Figure 4.2.1 Work Screen of Soil Gas Survey

5.0 In Situ Respiration Test

5.1 Background

In an ideal bioventing site, the active aerobic activities consume a large quantity of O_2 and generate more CO_2 in the soil gas at the contaminant site. The in situ respiration test is conducted at a contaminated site by injecting ambient gas along with helium into the subsurface and monitoring the variation of O_2 and CO_2 concentrations. The purpose of using helium is to indicate whether there is any gas leakage from the subsurface. The change of helium gas concentration should be less than 10% over a period of a day or so. Based on the information collected, we calculate the biodegradation rate and decide whether the site is a suitable candidate for bioventing.

However, because it is not easy to measure the biodegradation rate directly through an in situ respiration test, an alternative parameter is used for this purpose. The parameter is called the oxygen utilization rate. The relationship between biodegradation rate and the oxygen utilization rate is determined by stoichiometry [Leeson and Hinchee, 1995] and can be simplified as Equation 5.1.

$$k_B = \frac{-k_o \bullet \theta_a \bullet \rho_{o2} \bullet C \bullet 0.01}{\rho_k} \qquad (5.1)$$

where

k_B: biodegradation rate (mg/kg-day)
k_o: oxygen utilization rate (%/day)
θ_a: gas-filled pore space or porosity (m^3 gas / cm^3 soil)
ρ_{o2}:   oxygen density (mg/L)
C: mass ratio of hydrocarbons to oxygen required for mineralization
ρ_k: soil bulk density (g/cm^3)

In most cases, while the parameters θ_a, ρ_{o2}, C and ρ_k are considered as constant at a site, the relationship between biodegradation rate and oxygen utilization rate becomes linear. Equation (5.2) represents this relationship:

$$k_B = -F_b \bullet k_o \qquad (5.2)$$

where

F_b: biodegradation factor (mg/kg/%), $F_b = \dfrac{\theta_a \bullet \rho_{o2} \bullet C \bullet 0.01}{\rho_k}$

The biodegradation factor is the biodegradation rate when the oxygen utilization rate equals 1.

The Table 5.1.1 shows a set of data collected at a bioremediation site. The first column lists the date and time the data were taken, the second column shows the elapsed time from the

initial time in hours, and the remaining columns record the concentrations of oxygen, carbon dioxide, and helium.

Figure 5.1.1 shows a plot of data in Table 5.1.1. The y-axis on the left is for both oxygen (diamond symbols) and carbon dioxide (cross symbols), the y-axis on the right is for helium concentration (triangle symbols), and the x-axis is for the elapsed time in hours. From collected oxygen and carbon dioxide data, we can draw a linear regression line for each set of data. The slope of the oxygen linear regression line is defined as the oxygen utilization rate in terms of percent per hour, which is 0.585%/hr in this example. The value of the oxygen utilization rate varies by the number of data points included in the regression analysis. Judgment from technical staff is necessary to find the appropriate set of data.

Table 5.1.1   In Situ Respiration Data

Date/Time (mm/dd/yr hr:min)	Time (hr)	Oxygen (%)	Carbon Dioxide (%)	Helium (%)
4/1/96 9:15	0.0	21.00	0.00	1.60
4/1/96 9:20	0.1	20.00	0.00	1.40
4/1/96 12:35	3.3	19.50	0.00	1.40
4/1/96 14:50	5.6	18.50	0.25	1.40
4/1/96 17:20	8.1	17.50	0.50	1.50
4/1/96 23:05	13.8	14.50	0.75	1.60
4/2/96 4:25	19.2	9.00	0.75	1.70
4/2/96 9:00	23.8	7.00	1.00	1.70
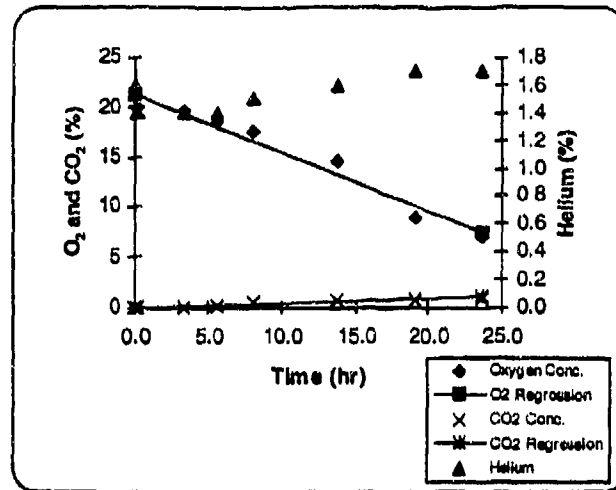
Figure 5.1.1   Plot of In Situ Respiration Test Data in Table 5.1.1

5.2 Tutorial

There are three subsections in the In Situ Respiration Testing section (Figure 5.2.1): Initial Soil Gas Readings, Data Analysis, and Biodegradation Rate Calculation. Each subsection is described in detail in Sections 5.2.1 through 5.2.5.
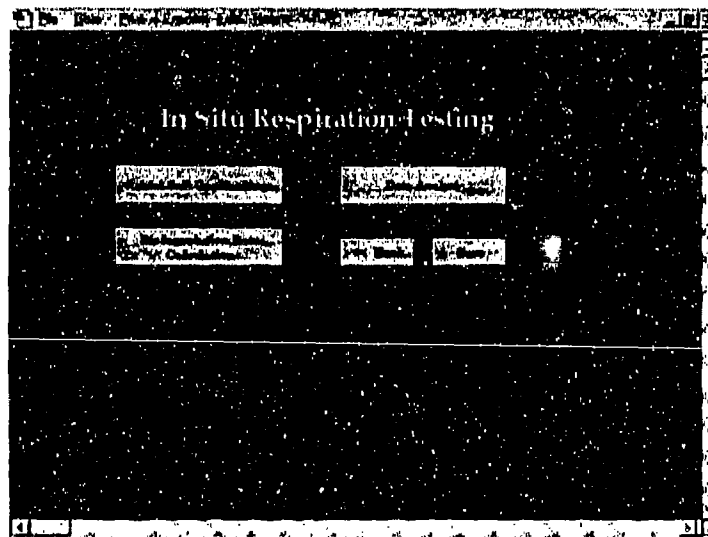
Figure 5.2.1   In Situ Respiration Test and Its Subsections

5.2.1 Initial Soil Gas Readings

The Initial Soil Gas Readings table shown in Figure 5.2.1.1 is used to record the soil gas data before the in situ respiration test. The data are organized by the monitoring points and depths. A total of 16 depths at various monitoring points can be recorded in the table.

Figure 5.2.1.1   Initial Soil Gas Readings Work Screen

5.2.2 Data Analysis

Figure 5.2.2.1 shows a standard In Situ Respiration Test work screen. The field data are presented in the table on the left, and the plot of these data is on the right. Because the soil gas concentration ranges are different among oxygen, carbon dioxide, and helium, two scales (y-axes) are used: one for oxygen and carbon dioxide on the left and one for helium on the right. The results of the linear regression analysis are shown in the lower part of the screen.

There are 20 pages available for this screen. Each page is used for a particular depth of a monitoring point. The monitoring point ID is inputted at the Monitoring Point area and the depth is inputted at the Depth of MP (ft) area. The combination of monitoring point name and depth becomes the official name of the page and will be used in the list box after updating. For example, the list name for monitoring point MP-D and 3′ depth is MP-D 3′. To update the list box names, a user needs to switch to a different page in the list box first, and then reselect the newly created list name. In other words, the list box is updated when a different page is selected.

5-4
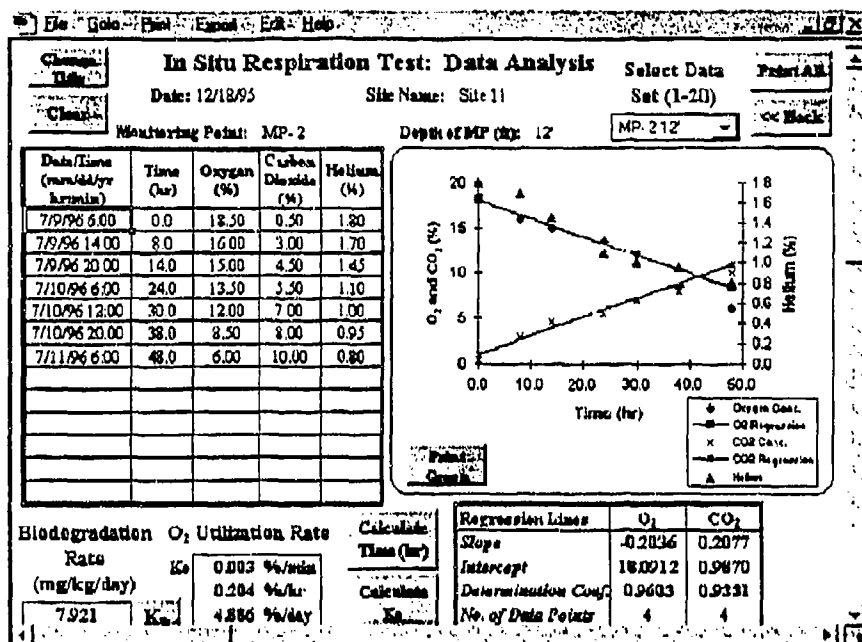
Figure 5.2.2.1   Work Screen of In Situ Respiration Test: Data Analysis

The format for date and time input is mm/dd/yr hr:mm, where mm/dd/yr is month/date/year, and hr:mm is hour:minute; for example, 04/01/96 03:20 is a proper input. Note that there is a blank space between the date and time. If the format is wrong or there is a blank row between two date and time entries, you will get a warning message as shown in Figure 5.2.2.2 when you calculate the elapsed time. When the warning message appears, click the **OK** button, carefully examine the data you input and make changes, then click the **Calculate K₀** button again to continue the calculation of oxygen utilization rate.
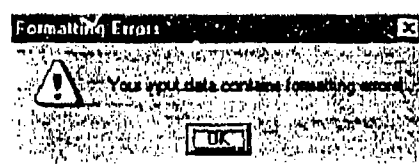
Figure 5.2.2.2   An Error Message for Wrong Format of Input Data

After completion of data input, the user clicks two buttons to complete the oxygen utilization calculation, first the **Calculate Time** button and then the **Calculate K₀** button. When the **Calculate Time** button is clicked, the elapsed time is calculated against the initial time (the time listed in the first row). If there are fewer than 13 rows of data, the elapsed time in the remaining rows is left blank. After the time has been calculated, a user clicks the **Calculate K₀** button, which brings up a dialog box to ask for the number of data to be included in the regression analysis (Figure 5.2.2.3). The number of data points should be more than 2 but not exceed 13, because one data point cannot draw a regression line but there are only 13 data points in the table.
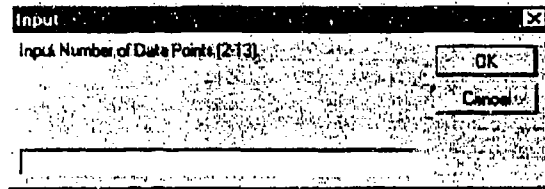
Figure 5.2.2.3   Specifying Number of Data Points for Calculating Oxygen Utilization Rate

When the **Calculate K₀** button is clicked, the statistical parameters of regression analysis (slope, intercep, determination coefficient, and number of data points) are presented in the lower right-hand corner and two regression lines are drawn for oxygen and carbon dioxide separately. The oxygen utilization rate is the slope of the regression line, and it is represented in three different units for convenience: %/min, %/hr, and %/day. The determination coefficient ranges from 0 to 1, with 1 indicating a perfect match between field data points and values estimated by the regression line, and 0 indicates a total mismatch. The user can visually compare the fitting of regression line with the field data points. Data points are distributed evenly around the regression line usually indicate a good match.

As discussed in the previous Section 5.1, because the variables on the right-hand side of Equation 5.1 are constants except the oxygen utilization rate at a specific site, the biodegradation rate becomes the multiplication of a unit biodegradation rate with the oxygen utilization rate as shown in Equation 5.2. The biodegradation rate shown at the lower left-hand corner of Figure 5.2.2.1 is the result of this calculation. By clicking the K_B button, the **Biodegradation Rate Calculation** work screen appears, and we can calculate the biodegradation rate. The details are discussed in Section 5.2.3. It should be pointed out that the biodegradation rate shown on the screen of Figure 5.2.2.1 is not to be considered correct until the biodegradation rate has been examined.

5.2.3 Biodegradation Rate Calculation

The **Biodegradation Rate Calculation** section provides a table format for Equations (5.1 and 5.2) as shown in Figure 5.2.3.1. The table can be used to calculate both biodegradation rate and unit biodegradation rate. The Unit K_B is a special case of biodegradation where the oxygen utilization rate equals 1 %/day. The calculated Unit K_B is used directly in the **In Situ Respiration Test** and **Periodic In Situ Respiration Test** to calculate the oxygen utilization rate.

Figure 5.2.3.1   Biodegradation Rate Calculation Work Screen

There are seven columns in the table for data calculation: Item, Data Range, Case 1, Case 2, Case 3, Final, and Unit K_B. The Data Range column provides a reference for users on the proper range of data that can be used in the calculation. For example, the gas-filled pore space or porosity is between 0.1 to 0.4 in normal situations. Oxygen density and soil bulk density depend on other factors. BVDT provides two separate tables for users to determine the appropriate values. When the **Ref** button is clicked, a table will show up on the screen. The details on how to use these tables are described later.

Columns Case 1, Case 2, and Case 3 are used to investigate the influence of different parameters on the biodegradation rate. By fixing the oxygen utilization rate, all four parameters in Equation 5.1 affect the biodegradation rate. Based on the user's judgment, the final values are decided and filled in the Final column. The biodegradation rate in the Final column represents the rate for this particular oxygen utilization rate, and the biodegradation rate in the Unit K_B column represents the rate for 1%/day oxygen utilization rate.

At many sites, the unit biodegradation rate can be used as a constant. Therefore, multiplying the Unit K_B by the oxygen utilization rate at a specific monitoring point gives the biodegradation rate at that point. That is reflected in the lower left-hand corner of Figure 5.2.2.1.

Two **Ref** buttons are the gateways to two reference tables: oxygen density and soil bulk density. Users need to obtain the proper values of them from the table to continue the calculation of biodegradation rate.

Tricks and Tips

a. The oxygen utilization rate inputted in Data Range (Figure 5.2.3.1) will appear in all columns except the Selected Parameters column. When a user evaluates the biodegradation rate, only one oxygen utilization rate is used.

b. No data needs to be entered in the Unit K_B column. All the data inputted in the Final column except the oxygen utilization rate will be reflected in the Unit K_B column. Thus, to obtain the unit biodegradation rate, the Final column has to be filled in even though the Case 1, Case 2, and Case 3 columns are not.

c. After the Unit K_B is calculated, the user can switch back to either In Situ Respiration Test or Periodic In Situ Respiration Test directly instead of using the **<<Back** button to go one level up. This can be achieved by clicking the **In Situ Respiration Test** button or the **Periodic In Situ Respiration Test** button.

5.2.3.1 Oxygen Density

Oxygen density varies with the temperature. Based on the information collected from literature [Leeson and Hinchee, 1995], the Oxygen Density Versus Temperature table is provided in BVDT by clicking the **Oxygen Density** button (Figure 5.2.3.1.1).

Figure 5.2.3.1.1   Oxygen Density Conversion Table Work Screen

This table lists the oxygen density versus temperatures. The temperature has two units, Celsius and Fahrenheit; and the density has two units as well, mg/L and lb/ft³. The temperature conversion factor is $1°F = 1.8°C + 32$. The conversion factor for density units is 1.0 mg/L $= 6.2429*10^{-6}$ lb/ft³.

To ease the use of this conversion table, a linear interpolation tool is provided at the lower part of the table. When a Celsius temperature is known, the temperature is entered into the blank area at the first column of the first row in the Linear Interpolation part of the table. The

equivalent Fahrenheit temperature and oxygen density are calculated automatically. When a Fahrenheit temperature is known, a user inputs it in the blank area in the second row. If the temperature is out of the range in the table (the range is 0 to 40°C), for example, -35°C, a N/A sign will appear at the density areas.
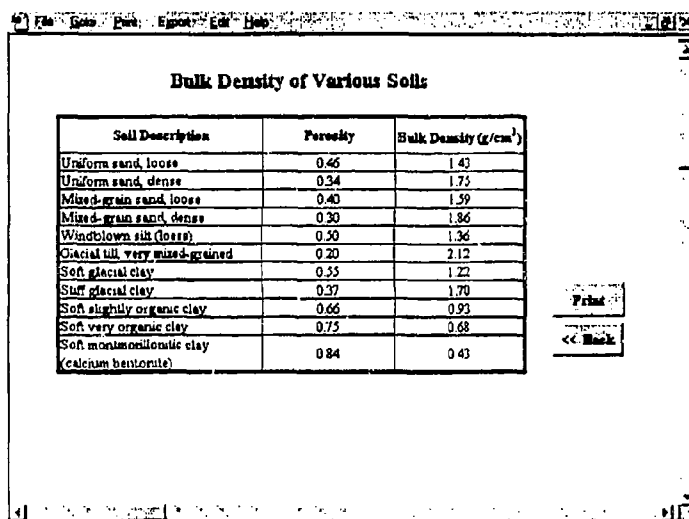
Because the soil bulk density is used during the biodegradation calculation, the user can return to the Biodegradation Rate Calculation work screen by clicking the **<<Back** button.

Tips and Tricks

Because the Linear Interpolation part of the table converts the temperature from Celsius to Fahrenheit or vice versa during the oxygen density calculation, the user can use this feature as a temperature conversion tool.

5.2.3.2 Soil Bulk Density

The Soil Bulk Density section under In Situ Respiration Test is a list of soil porosities and densities for various soil types [Peck et al., 1962]. The information is shown in a table as Figure 5.2.3.2.1. Because the soil bulk density is used during the biodegradation calculation, the user can return to the Biodegradation Rate Calculation work screen by clicking the **<<Back** button.

Bulk Density of Various Soils

Soil Description	Porosity	Bulk Density (g/cm³)
Uniform sand, loose	0.46	1.43
Uniform sand, dense	0.34	1.75
Mixed-grain sand, loose	0.40	1.59
Mixed-grain sand, dense	0.30	1.86
Windblown silt (loess)	0.50	1.36
Glacial till, very mixed-grained	0.20	2.12
Soft glacial clay	0.55	1.22
Stiff glacial clay	0.37	1.70
Soft slightly organic clay	0.66	0.93
Soft very organic clay	0.75	0.68
Soft montmorillonitic clay (calcium bentonite)	0.84	0.43

Figure 5.2.3.2.1   Soil Bulk Density Work Screen

6.0 Soil Gas Permeability and Radius of Influence

6.1 Background

One of the goals of a bioventing pilot test is to find out how to deliver ambient air to the subsurface in a full-scale test. Two physical properties of soils are of importance, the soil gas permeability (intrinsic permeability) noted as k (unit: cm², or darcy = 1x10⁻⁸cm²) and soil gas radius of influence noted as RI (unit: ft). They indicate whether the ambient air can pass through the soil and how far the air can travel in the soil from the vent well. Based on the information collected from the field test, these two parameters are calculated in this section.

6.1.1 Soil Gas Permeability

The range of soil gas permeability varies widely. It depends on many factors, such as grain size, soil uniformity, porosity, and moisture content. The typical soil gas permeability has the following ranges of variation:

Soil Type	k (darcy)
coarse sand	100 - 1000
medium sand	1 - 100
fine sand	0.1 - 1.0
silts/clay	< 0.1

Many methods are available to measure the soil gas permeability in the field. Two of these methods are used in the Bioventing Design Tool: the dynamic method and the steady-state method.

6.1.1.1 Dynamic Method of Soil Gas Permeability Test

This test is conducted at a single well under constant air injection or extraction while pressure changes are measured at several soil gas monitoring points. Equation (6.1) describes the dynamic changes in soil gas pressure/vacuum.

$$P' = \frac{Q}{4\pi m \frac{k}{\mu}} \bullet \frac{-0.5772 - \ln(r^2 e \mu) + \ln(t)}{4kP_{atm}} \qquad (6.1)$$

where
P':   gauge pressure measured at distance r from the vent well at time t (g/cm-s²)
m: stratum thickness, generally the vent well screened interval (cm)
r: radial distance from monitoring point to vent well (cm)

k: soil gas permeability (cm^2)
m: viscosity of air (1.8×10^{-4} g/cm-s at 18°C)
e: soil's air-filled void volume (dimensionless)
t: time from the start of the test (s)
Q: volumetric flowrate from the vent well (cm^3/s)
P_{atm}: ambient air pressure (at sea level 1.013×10^6 g/cm-s^2)

The above equation indicates that the relationship between P´ and ln(t) is linear with a slope A of

$$A = \frac{Q}{4\pi m \dfrac{k}{\mu}} \qquad (6.2)$$

which yields the relationship between k and Q as

$$k = \frac{Q\mu}{4A\pi m} \qquad (6.3)$$

The general approach of using dynamic method is to conduct a field air permeability test. This method involves obtaining a series of gauge pressures versus time at various monitoring points, selecting a representative regression line for the data set, and calculating the slope A of that linear regression line. Then, air permeability, k, is calculated by substituting all known values into the right hand-side of Equation (6.3).

6.1.1.2 Steady-State Method of Soil Gas Permeability Test

The steady-state method is based on the steady-state solution to Eq. (6.1):

$$k = \frac{Q\mu \ln\left(\dfrac{R_w}{R_I}\right)}{H\pi P_w\left[1 - \left(\dfrac{P_{atm}}{P_w}\right)^2\right]} \qquad \text{In air extraction condition} \qquad (6.4)$$

$$k = \frac{Q\mu \ln\left(\dfrac{R_w}{R_I}\right)}{H\pi P_{atm}\left[1 - \left(\dfrac{P_w}{P_{atm}}\right)^2\right]} \qquad \text{in air injection condition} \qquad (6.5)$$

where
R_w: radius of venting well (cm)
H: depth of screen (cm)
R_I: maximum radius of venting influence at steady state (cm)
P_w: absolute pressure at the venting well (g/cm-s^2)

Because all the variables on the right-hand side of the equations are measurable, the k value can be calculated using this steady-state method.

6.1.2 Soil Gas Radius of Influence

The soil gas radius of influence, R_I, is defined as the maximum distance from the air extraction or injection well where vacuum or pressure (soil gas movement) occurs. For bioventing practice, we adopt the following method to determine the soil gas radius of influence: (1) take the pressure measurement in several monitoring points away from a venting well for a time period, (2) use the steady set of data to plot the log of the pressure against the distance from the vent well, and (3) select a linear regression line. The radius of influence is the distance from the vent well where the pressure is 0.1 inch of water, that is, the intersection of the regression line with the $y = 0.1$ line.

6.2 Tutorial

Figure 6.2.1 shows the work screen for calculating soil gas permeability and radius of influence. For different situations, a user may select the dynamic method or the steady-state method to calculate the soil gas permeability. A brief recommendation on which method to choose from is provided in the text box next to the button. One can access one of two permeability calculation methods by clicking either the button or the text box.
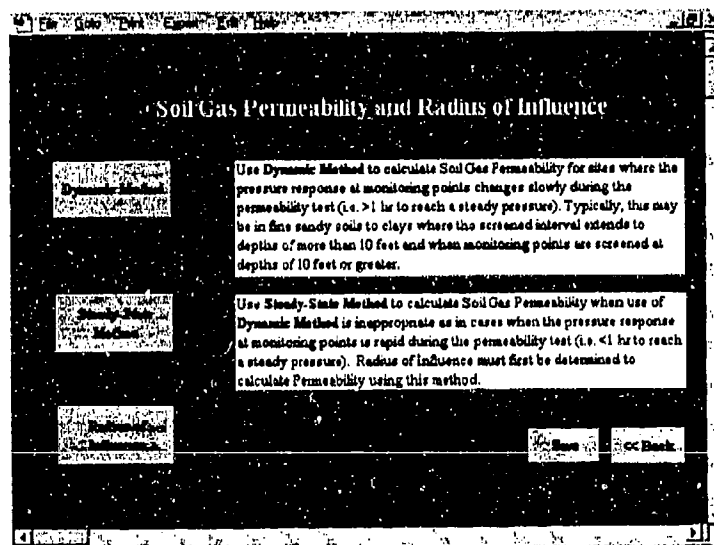
Figure 6.2.1   Work Screen of Soil Gas Permeability and Radius of Influence

6.2.1 Determining Soil Gas Permeability Using Dynamic Method

Five parameters are required to calculate the soil gas permeability using dynamic method: flow rate, stratum thickness, viscosity, elapsed time, and pressure (Figure 6.2.1.1). After the elapsed time is inputted at the first column, users need to click the **Calculate ln(time)** button to validate the time values and obtain the natural log of time. Nine sets of pressure data can be inputted in the table. The cells below "Vacuum (inches of water) at Monitoring Points (MPs)" are for inputting names of pressure data, such as MP-1.

After inputting all the data, users can move to the graph part by clicking the **Graph** button. In the graph, the x-axis is for ln(time), the y-axis is for pressure, the blue diamonds are for data points, and the red line is for the regression line. From the list box on the right-hand side of the work screen, users can select which set of pressure data to be used to calculate the soil gas permeability. As discussed in Section 6.1.1.1, the slope of the regression line is used to calculate the permeability. Users have flexibility in choosing the number of data points to be included in the regression line analysis by clicking the **Calculate k** button (Figure 6.2.1.2). By properly entering the number of data points to be included in the dialog box (Figure 6.2.1.3), the regression line is redrawn, and the permeability value is updated in the text box in units of darcy.

The Print button generates a final output including both the data table and the graph as shown in Figure 6.2.1.4.

Figure 6.2.1.1   Work Screen of Data Part of Soil Gas Permeability Calculation Using Dynamic Method
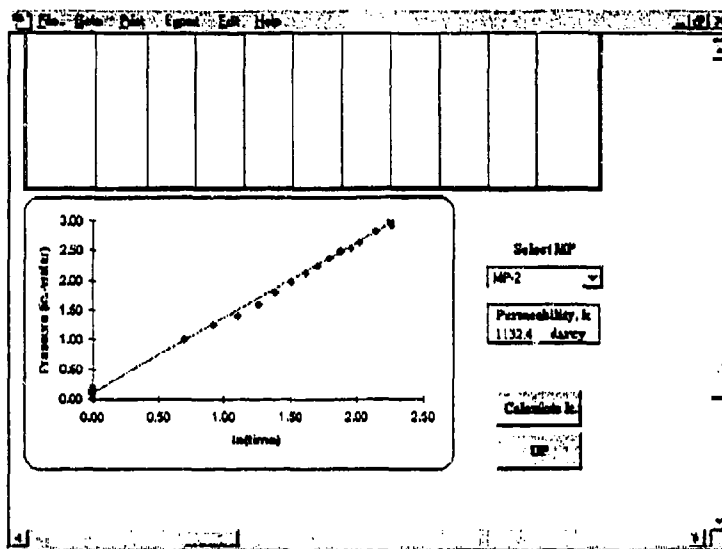
Figure 6.2.1.2   Work Screen of Graph Part of Soil Gas Permeability Calculation Using Dynamic Method
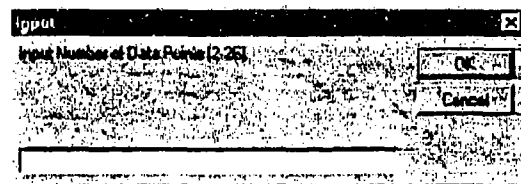
Figure 6.2.1.3   Dialog Box for Specifying Number of Data Points to Calculate

Soil Gas Permeability (Dynamic Method)

Site Name: Site 11

Operator(s):

Date: 3/6/96

Volumetric flow rate from the vent well (cm^3/s)								Q	1000.00
Stratum thickness, generally the vent well screened interval (cm)								m	1000.00
Viscosity of Air (1.80x10^{-04} g/cm-s at 64.4 °F (18 °C)								μ	1.80E-04

Elapsed Time (min.)	ln(time)	Vacuum (inches of water) at Monitoring Points (MPs)								
		MP-1	MP-2	MP-3	MP-4	MP-5	MP-6	MP-7	MP-8	MP-9
0.00	0.00	0.00	0.00	0.00						
0.50	0.00	0.10	0.10	0.40						
1.00	0.00	0.21	0.21	1.40						
2.00	0.69	1.00	1.00	3.60						
2.50	0.92	1.25	1.25	4.00						
3.00	1.10	1.41	1.41	4.40						
3.50	1.25	1.60	1.60	5.00						
4.00	1.39	1.80	1.80	5.30						
4.50	1.50	1.98	1.98	5.60						
5.00	1.61	2.12	2.12	5.80						
5.50	1.70	2.25	2.25	6.00						
6.00	1.79	2.37	2.37	6.10						
6.50	1.87	2.48	2.48	6.20						
7.00	1.95	2.55	2.55	6.30						
7.50	2.01	2.63	2.63	6.40						
8.50	2.14	2.82	2.82	6.50						
9.50	2.25	2.92	2.92	6.50						
10.00	2.30	3.00	3.00	3.00						
10.50	2.35	2.96	3.30	2.00						
11.00	2.40	2.00	3.30	2.00						
12.00	2.48	3.00	2.30							
14.00	2.64	2.90								
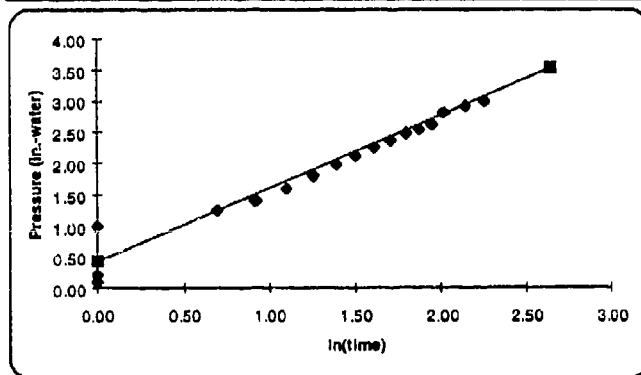
MP: MP-1

Permeability, k	
1220.73	darcy

Figure 6.2.1.4   Output of Soil Gas Permeability Calculation Using Dynamic Method

6.2.2 Determining Soil Gas Permeability Using Steady-State Method

The steady-state method for determining soil gas permeability is more straightforward than the dynamic method. The work screen is shown in Figure 6.2.2.1. The user needs to input the following parameters: flow rate, viscosity of air, ambient pressure, absolute pressure at the venting well, radius of venting well, and depth of screen. Users can input the soil gas radius of influence from the previous calculation, or provide a more reasonable value based on the previous calculation. Because the equations for permeability differ for injection and extraction, two permeability values are calculated. The radius of influence calculated in the next section is shown below the table as a reference. A user inputs "Radius of Influence-Previously determined" based on technical judgment.

Soil Gas Permeability (Steady-State Method)

Site Name: Site 11   Date: 3/28/96

Item	Symbol	Value	Unit
Volumetric Flow Rate from the Vent Well	Q	19821.79	cm³/s
Viscosity of Air (1.80x10⁻⁰⁴ g/cm-s at 64.4 °F (18 °C))	u	1.80E-04	g/cm-s
Ambient pressure (at sea level 1.013 x 106 g/cm-s²)	Pam	9.46E+05	g/cm-s²
Absolute Pressure at the Vent Well	Pw	9.96E+05	g/cm-s²
Diameter of Vent Well / 2	Rw	2.54	cm
Length of Screened Interval	H	1233.60	cm
Radius of Influence-Previously Determined	Rᵢ	3048.00	cm
Soil Gas Permeability (for Vacuum Well)	k	6.81	darcy
Soil Gas Permeability (for Air Injection Well)	k	6.47	darcy

Rᵢ (Previously Calculated):   NA   ft   =   NA   cm   << Back   Print

Figure 6.2.2.1   Work Screen of Soil Gas Permeability Calculation Using Steady-State Method

6.2.3 Soil Gas Radius of Influence

The work screen for calculating soil gas radius of influence is composed of one data table and a graph. In the data table, there are columns for time and soil gas pressures; and rows for MP names, depth, and distance (Figure 6.2.3.1). There are 15 columns for pressure data. In the field, pressure data are taken at a certain time interval within a period of 2 to 4 hours. However, only one set of pressure data is used for calculating the radius of influence. A user can choose any data set by clicking the option button in the time column.

The cells to the right of the MP cell are for monitoring point names, such as MP-1. The monitoring point depths can be inputted in the row labeled Depth. The distance form one

monitoring point to the well is inputted in the row labeled distance. Some columns may be left blank if there are not enough monitoring points.

The sequence in which the monitoring points are listed does not matter because the calculation of radius of influence is based on the regression line of the entire data set. The closer points can be listed on the right-hand side. However, when calculating radius of influence, the number of data points to be included is counted from left to right. Make sure all of those data points are included for the regression line analysis.

Radius of Influence

Site Name: Site 11   Operator(s): A. BB   Date: 3/15/96

MP	MPA	MPA	MPA	MPB	MPB	MPB	MPC	MPC	MPC	MPD	MPD	MPD	MP
Depth	3.0'	6.0'	9.0'	3.0'	6.0'	9.0'	3.0'	6.0'	9.0'	3.0'	6.0'	9.0'	3(
Distance (ft)	4.00	4.00	4.00	10.00	10.00	10.00	20.00	20.00	20.00	40.00	40.00	40.00	50.(
Time (min.)	Vacuum (in. H₂O)												
0.0													
6.0													
12.0	0.45	0.43	0.70	0.30	0.43	0.20	0.02	0.20	0.30	0.05	0.07	0.32	0.3
18.0													
24.0	0.45	0.43	0.38	0.25	0.13	0.08							
30.0													
36.0	0.80	0.80	0.70	0.40	0.30	0.30	0.20	0.20	0.20	0.05	0.07	0.05	0.0
42.0	0.80	0.70	0.75	0.68	0.66	0.65	0.58	0.40	0.35	0.33	0.22	0.21	0.2
48.0													
54.0	0.45	0.43	0.70	0.30	0.43	0.20	0.02	0.20	0.30	0.05	0.07	0.32	0.3

R₁(ft): 29.27

Regression Statistics

Slope	-0.032
Intercept	0.8592
Determination Coef.	0.9504

Figure 6.2.3.1   Work Screen of Calculating Radius of Influence

In the graph part of the screen, the x-axis is for distance, and the y-axis is for pressure (plotted in a 10-based logarithm scale). All data points are represented by the blue diamond symbols, and the regression line is red. By choosing a different number of data points to be included in the calculation, the regression line changes, and so does the radius of influence value.

After all data have been inputted, click the **Calculate R₁** button in Figure 6.2.3.1 to calculate the radius of influence. Because R₁ is determined by the slope of the regression line in the graph, the number of data points included in the regression analysis is important. The statistical information for the included data points is shown in the lower left corner of the figure. The user is asked for the number of data points to be included as shown in Figure 6.2.3.2.
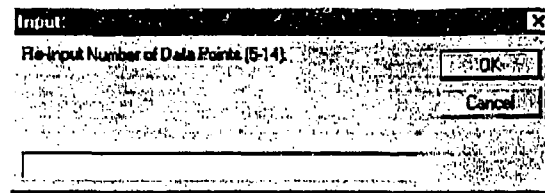
Figure 6.2.3.2   Dialog Box for Determining the Number of Data Points for R_i Calculation

The printout of the radius of influence calculation is shown in Figure 6.2.3.3.

Radius of Influence

Site Name: Site 11   Operator(s): A. BB   Date: 3/15/96

MP	MPA	MPA	MPA	MPB	MPB	MPB	MPC	MPC	MPC	MPD	MPD	MPD	MPE	MPE	MPE
Depth	3.0'	6.0'	9.0'	3.0'	6.0'	9.0'	3.0'	6.0'	9.0'	3.0'	6.0'	9.0'	3.0'	6.0'	9.0'
Distance (ft)	4.00	4.00	4.00	10.00	10.00	10.00	20.00	20.00	20.00	40.00	40.00	40.00	50.00	50.00	50.00
Time (min.)	Vacuum (in. H₂O)														
0.0 ○															
6.0 ○															
12.0 ○	0.45	0.43	0.70	0.30	0.43	0.20	0.02	0.20	0.30	0.05	0.07	0.32	0.35	0.72	0.23
18.0 ○															
24.0 ○	0.45	0.43	0.18	0.25	0.13	0.08									
30.0 ○															
36.0 ◉	0.80	0.80	0.70	0.40	0.30	0.30	0.20	0.20	0.20	0.05	0.07	0.05	0.01	0.00	
42.0 ○	0.80	0.70	0.75	0.68	0.66	0.65	0.58	0.40	0.35	0.33	0.22	0.21	0.20	0.15	0.13
48.0 ○															
54.0 ○	0.45	0.43	0.70	0.30	0.43	0.20	0.02	0.20	0.30	0.05	0.07	0.32	0.35	0.72	0.23

R_i (ft): 29.27

Regression Statistics	
Slope	-0.032
Intercept	0.8592
Determination Coef.	0.9504
No. of Data Points	10

Figure 6.2.3.3   Printout of Radius Influence Calculation

6.3 Tips and Tricks

a)   Use the Dynamic Method to calculate soil gas permeability for sites where the pressure response at monitoring points changes slowly during the permeability test (i.e. >1 hr to reach a steady pressure). Typically, this may be in fine sandy soils to clays where the screened interval extends to depths of more than 10 feet and where monitoring points are screened at depths of 10 feet or greater.

b)   Use the Steady-State Method to calculate soil gas permeability when use of the Dynamic Method is inappropriate as in cases where the pressure response at monitoring points is rapid

during the permeability test (i.e. <1 hr to reach a steady pressure). Radius of influence must first be determined to calculate permeability using this method.

Part IV. System Design

7.0 Blower Selection

7.1 Background

A blower is used to drive ambient air through contaminated soils to enhance the microbial activities in an oxygen-limited situation. Proper sizing and selection of a blower are essential to meet the requirements of air flow and backpressure drop. System pressure drop includes (a) the backpressure due to the vent wells and formation in an air injection configuration (or the vacuuminduced in the wells and formed in an extraction configuration), and (b) any pressure drop in the system piping and off-gas treatment system.

Choosing the wrong blower can result in an inability to deliver sufficient oxygen or a significantly shortened blower life. Care must be taken to select the type of blower that can deliver the required air flow at the expected pressure. It is better to select and size a blower that will be operating somewhere in the middle of its performance range. This ensures that the blower will not be overstressed, causing it to burn out in a shortened time. It also prevents selection of an oversized blower which can save money in the long run.

The flow rate is basically dependent on the oxygen utilization rate, volume of contaminated soil, and porosity. Equation (7.1) presents the relationship between these parameters and the flow rate.

$$Q = \frac{K_o V \theta_a}{(20.9\% - 5\%) \times 60 \frac{min}{hr}} \tag{7.1}$$

where

Q:	flow rate (ft^3/min, or cfm)
K$_o$:	oxygen utilization rate (%/hr)
V:	volume of contaminated soil (ft^3)
θ_a:	gas-filled void volume

The equation is based on the total oxygen consumption within 1 hour in the entire block of contaminated soils. To ensure adequate oxygen supplies, a minimum of 5% oxygen concentration is needed, because microbial activity is not oxygen-limited above approximately 1 to 2% oxygen concentration. The oxygen utilization rate is determined from in situ respiration tests during a pilot test.

The specification of soil vapor extraction blowers usually contains the following information: frequency (Hz), horsepower (HP), rotation per minute (RPM), maximum vacuum pressure (inches of water), maximum flow rate, and net weight. A performance chart is usually attached. Figure 7.1.1 illustrates a typical performance chart with flow rate as the x-axis and vacuum pressure as the y-axis. The curve on the left is for 50 Hz and the curve on the right is for

60 Hz. Selecting a vacuum pressure between 20 to 50 in of water helps to achieve better performance from the blower.

Blower Performance Chart
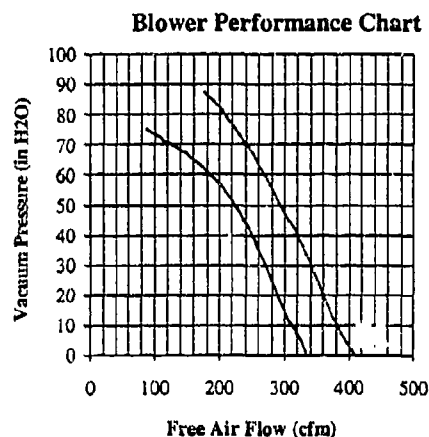
Figure 7.1.1   Blower Performance Chart

7.2 Flow Rate Calculation

The flow rate calculation is conducted in the work screen shown in Figure 7.2.1. Based on Equation 7.1, users need to provide the information necessary to calculate the required flow rate which is highlighted in the table. Three data are required for this calculation: oxygen utilization rate, volume of contaminated soil, and porosity or gas-filled void volume.

As comparison to required flow rate calculated from Equation 7.1, users are required to enter Empirically Derived Flow Rate(s) from soil gas permeability test. Based on both calculated and empirically derived flow rates, the reasonable flow rate can be selected. Columns Case 1 to Case 3 provides the space for adjusting the flow rate calculation before selecting the final value. The column Final is required to be filled in so that the Selected Flow Rate can be used in Blower Selection and Well Spacing Calculation.

Flow Rate Calculation

Site Name: Site 11   Date: 7/29/96
Operator(s): L. King

	Case 1	Case 2	Case 3	Final
Oxygen Utilization Rate (%o/hr)	0.4			2.0
Volume of Contaminated Soil (cuft)	15000			10000
Porosity	0.3			0.2
Flow Rate Required to Satisfy O_2 Demand (cfm)	1.9	0.0	0.0	4.2
Empirically Derived Flow Rate Test 1 (cfm)				
Empirically Derived Flow Rate Test 2 (cfm)				
Empirically Derived Flow Rate Test 3 (cfm)				
Required Flow Rate (cfm)				20.0

Clear
<< Back
Save
Print

Figure 7.2.1 Work Screen of Flow Rate Calculation

7.3 Blower Selection

The Blower Selection work screen is shown in Figure 7.3.1. Above the working table, there are two paragraphs of text explaining the considerations for selecting a proper blower. The text reads: "A blower provides the driving force to move air through the bioventing system. In selecting the blower size, one must consider the required air flow rate and the total system pressure drop. System pressure drop includes (1) the backpressure due to the vent wells and formation in an air injection configuration (or the vacuum induced in the wells and formation in an extraction configuration), plus (2) any pressure drop in the system piping and off-gas treatment system."

Blower Selection

Site Name: Site 11   Date: 3/28/96
Operator(s): abcdef afaskdfj asdf

A blower provides the driving force to move air through the bioventing system. In
selecting the blower size, one must consider the required air flow rate and the total
system pressure drop. System pressure drop includes (1) the backpressure due to the
vent wells and formation in an air injection configuration (or the vacuum induced in the
wells and formation in an extraction configuration) plus (2) any pressure drop in the
system piping and off-gas treatment system.

The required pressure or vacuum in the well is a function of the soil gas permeability,
which is determined through field tests.

	Blower Model	Blower Size (HP)	Pressure (in H_2O)	Flow Rate (cfm)	Required Flow Rate (cfm)	Check
Blower 1	R1	2.00	20.00	120.00	20.00	yes
Blower 2	R2	1.00	20.00	70.00	20.00	yes
Blower 3	R3	0.60	20.00	70.00	20.00	
Blower 4					20.00	
Blower 5					20.00	
Blower 6					20.00	

Save   Database   Clear   Print   << Back

Figure 7.3.1   Work Screen of Blower Selection

The selected flow rate discussed in previous section is shown in the column Required
Flow Rate. The data in all other four columns can be obtained from manufacturer specification
sheet. From the performance chart, one can find the designed flow rate of a blower at a specified
pressure. The user must compare this flow rate against the required flow rate and decide whether
it is appropriate. Usually, more than one blower is available for such comparison.

It is necessary to verify whether the required blower can meet the most demanding
conditions in the field, i.e., when oxygen demand is highest and soil gas permeability is lowest due
to seasonal variations. A slightly overdesigned blower can be bypassed through an arrangement
made in the plumbing system to reduce the air flow into the soil.

8.0 Vent Well and Monitoring Point Spacing

8.1 Vent Well Spacing

8.1.1 Background

Spaces between vent wells are determined by the radius of influence of the injected ambient air. Three factors should be considered in the calculation of radius of influence: pressure, flow rate, and oxygen utilization rate. For convenience, only pressure radius of influence is measured and calculated in the soil permeability test in the current bioventing protocol. To include all three factors in the calculation of radius of influence, the estimated radius of influence is needed.

Assuming the vent wells are in vertical position, and the radius of influence is much larger than the well radius, Equation (8.1) can be used for estimating radius of influence considering both air flow and oxygen utilization:

$$R_I = \sqrt{\frac{Q \times (20.9\% - 5\%)}{\pi \times h \times k_o \times \theta_a}} \tag{8.1}$$

where
  R_I: radius of influence (ft)
  Q: air flow rate (ft³/day)
  k_o: oxygen utilization rate (%/day)
  θ_a: air-filled porosity
  h: aerated thickness (ft)

To ensure adequate oxygen supplies, a minimum of 5% oxygen concentration is needed, because microbial activity is not oxygen-limited above approximately 1 to 2% oxygen concentration. That is why the oxygen concentration of 20.9% is subtracted by 5%.

The final radius of influence should take into account both the pressure measurements and oxygen utilization. This incorporates all three of the key factors: pressure connection, air flow, and oxygen utilization into the radius of influence calculation.

8.1.2 Vent Well Spacing Calculation

Figure 8.1.2.1 shows the work screen for the Vent Well Spacing Calculation. The upper part of the table is used for calculating radius of influence from the oxygen utilization rate based on Equation (8.1). The Empirical Radius of Influence is the one calculated from pressure measurements (Chapter 6.0 Soil Gas Permeability and Radius of Influence). Based on the

judgment of users, a final radius of influence can be decided upon. The vent well spacing is usually 1 to 1.5 times the radius of influence. When multiple wells are installed, some consideration may be given to airflow patterns. In theory, airflow lines may develop such that "dead zones" are created. However, given vertical and horizontal flow paths and diffusion, these dead zones are unlikely to occur, and we do not recommend routinely compensating for them.

The table in Figure 8.1.2.1 allows four cases to be calculated. The first column had default values from previous calculation, such as Flow Rate and Air-filled Porosity. Then the Radius of Influence is calculated based on Equation 8.1. From columns Case 2 to Case 4, users have the flexibility to change the values of flow rate and porosity to investigate the proper value of them and determine the radius of influence. By comparing the calculated and empirical radius of influence, users can decide the required radius of influence to support the well spacing selection, which is usually 1 to 1.5 times of the required radius of influence.

Vent Well Spacing Calculation

Site Name: Site 11   Date: 1/2/96

	Case 1	Case 2	Case 3	Case 4
Flow Rate (cfm)	20.0	20.0		
Oxygen Utilization Rate (%/day)	4.0	4.0		
Air-filled Porosity	0.4	0.3		
Aerated Thickness (ft)	20.0	20.0		
Radius of Influence (ft)	67.5	85.4		
Empirical Radius of Influence (ft)	138.3			
Required Radius of Influence (ft)	70.0			
Well Spacing (ft)	100.0			

Figure 8.1.2.1   Work Screen of Well Spacing Calculation

8.2 Soil Gas Monitoring Point Spacing

Soil gas monitoring points are an integrated part of a bioventing system to monitor the changes of pressure and soil gas. To the extent possible, the monitoring points must be located in contaminated soils with greater than 1,000 mg/kg of total petroleum hydrocarbon. If monitoring points are not located in contaminated soil, meaningful in situ respiration data cannot be collected.

In addition, monitoring points should be located with consideration given to soil gas permeability testing and radius of influence determination. Monitoring points should be located at varying distances from the vent well. The distances from the vent well will vary depending on soil type. The suggested soil gas monitoring point spacing is shown in Table 8.2.1.

Table 8.2.1 Suggested Soil Gas Monitoring Point Spacing

Suggested Soil Gas Monitoring Point Spacing

Soil Type	Depth to Top of Vent Well Screen (ft)	Spacing Interval (ft)
Coarse Sand	5	5-10-20
	10	10-20-40
	>15	20-30-60
Medium Sand	5	10-20-30
	10	15-25-40
	>15	20-40-60
Fine Sand	5	10-20-40
	10	15-30-60
	>15	20-40-80
Silts	5	10-20-40
	10	15-30-60
	>15	20-40-80
Clays	5	10-20-30
	10	10-20-40
	>15	15-30-60

9.0 Installations

9.1 Background

During a bioventing project, there are one or more monitoring wells, vent wells, and soil gas monitoring points involved. Some exist, and some are constructed for the project. All construction work needs to be documented properly. This section provides several tools to support such an effort.

9.2 Tutorial

9.2.1 Vent Well Information and Diagram

The Vent Well Information section presents a well construction diagram, and several tables containing important information about the well. Figure 9.2.1.1 shows the work screen of the section. By clicking the list box above the diagram, users can select one of 10 vent well pages. The default page name in the list box is "Vent Well x", where x is a numerical number from 1 to 10. If the vent well name is provided, it will be used as the page. For example, if the vent well is called VW-1 as shown in Figure 9.2.1.1, the page name is "VW-1".

Figure 9.2.1.1   Work Screen of Vent Well Information

The vent well construction diagram is not drawn in scale. Each major portion of the well has one data table pointing toward it. For example, the Surface Completion table in Figure 9.2.1.1 points to the top of the diagram, and has space for the following information: Size, Type, Well Cap, and Lock #. The names of the vent well components are listed on the left side of the well diagram.

Two tables on the right side of the work screen provide the geographic information of the well. They might be seen only partially because the size of the table exceeds the screen area in a standard VGA mode. Users can use the scroll bar to slightly scroll to the right. Any coordinate system such as geographic or state plane coordinates can be recorded in the Location Coordinates table.

9.2.2 Monitoring Well Information and Diagram

Soil gas monitoring well construction is a primary part of bioventing field activities. This subsection provides a convenient tool to document the well construction graphically. When the **Monitoring Well Information and Diagram** button is selected from **Installations**, the data input area of monitoring well information is shown first (Figure 9.2.2.1). There are ten monitoring well pages available. Users can choose one of these wells from the list box. To change the name of the monitoring well, users type a new well name in **Well I.D.** area. This newly inputted name will take effect as soon as another monitoring well is selected from the Well I.D. list box. If the user does not provide a well name, the default name is "New MP-X" where x ranges from 1 to 10.

The information about the well, such as elevation, coordinates (either geographic or state plane coordinates), well I.D., and driller are all listed on the right-hand side of the screen. These data are all specific to the individual well.

Figure 9.2.2.1   Work Screen of Monitoring Point Information User Input

The table in Figure 9.2.2.1 is used to input vertical dimension information about the well construction and diagram. There are 23 rows and five columns in the table. Each row corresponds to a layer in the well diagram. The column **Layer** is used to specify the material of the layer by choosing the material type. By clicking the arrow keys (up and down), nine material types are available: Bentonite, Gravel, Sand, Back-fill, Concrete, Cement, Grout, Other, and None. Because **Start Depth** equals the end depth of the previous layer, users need to input only in the **End Depth** column. These depths are measured from the ground surface of the well. If there is a monitoring point in the layer, users can select "yes" by selecting the up/down arrow in the MP column. The **Thickness** column calculates the thickness of the layer by subtracting the start depth from the end depth. Users do not need to input data into this column.

After all of the necessary information is inputted, clicking the **Draw MP** button will draw a well diagram in scale vertically and display it as shown in Figure 9.2.2.2. This diagram illustrates the construction of the top part of the monitoring point without a scale. However, the layer construction is drawn with proportion to its dimension, and is marked with different patterns. The pattern legend is located to the left of the diagram. The printout of the diagram is shown in Figure 9.2.2.3.
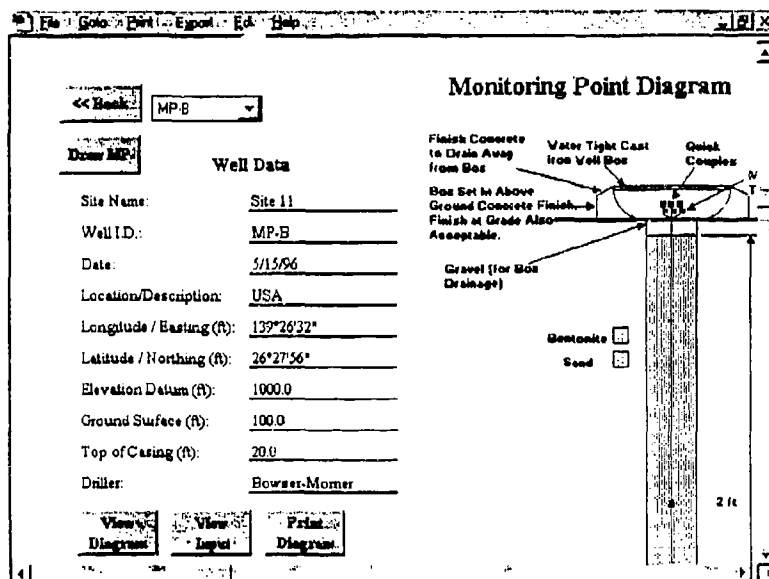

Figure 9.2.2.2   Work Screen of Monitoring Point Diagram

Monitoring Point Diagram

Well Data

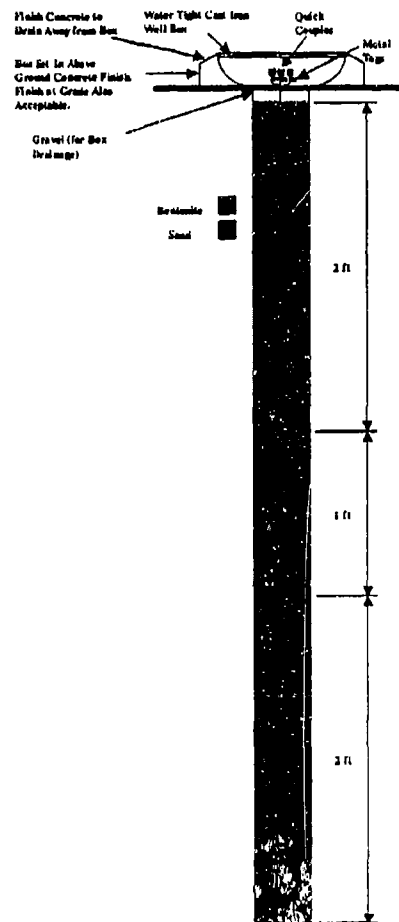|	
Site Name:	USA AFB, Site 123
Well I.D.:	MP-A
Date:	5/3/96
Location/Description:	USA
Longitude / Easting (ft):	128o30'25"
Latitude / Northing (ft):	35o00'30"
Elevation Datum (ft):	1000.0
Ground Surface (ft):	120.0
Top of Casing (ft):	121.0
Driller:	Bowser-Morner

Figure 9.2.2.3   Printout of Monitoring Point Diagram

9.2.3 Installation Summary Table

The Installation Summary Table tabulates all wells installed at a site with their primary information: Installation Type, ID, Installation Date, and Comments. The structure of the table is simple. Eighteen wells can be listed in the table. Three function buttons are available: **Clear**, **<<Back**, and **Print**. Figure 9.2.3.1 shows the work screen of the table.

Figure 9.2.3.1   Work Screen of Installation Summary Table

9.2.4 Initial Depths to Groundwater and Free Product

The Initial Depths to Groundwater and Free Product table records both water levels and product levels at the beginning of the project. The following data are entered into the table: Well Identification, Well Type, Depth to Product, Depth to Water, and Product Thickness. The last item is calculated automatically by subtracting depth to product from depth to water. If there is no product present, i.e., the depth to product is empty, the "NA" sign shows up in the Product Thickness column. This table can also be accessed from **Site Characterization**. See discussions in Section 4.1.

Initial Depths to Groundwater and Free Product

Site Name: Site 11

Operators: L. King

Date: 1/1/96

Well Identification	Well Type	Depth to Free Product (ft)	Depth to Groundwater (ft)	Free Product Thickness (ft)
MW-1	Monitoring Well	3.00	3.12	.12
MW-2A	Monitoring Well	2.89	3.00	.11
MW-2B	Monitoring Well	3.00	3.20	.2
MW-3	Monitoring Well	3.50	4.00	.5
MW-5	Monitoring Well		2.33	NA
MW-6	Monitoring Well	5.00		NA

Site Charact.

Installation

Print

Save

Clear

Change Title

Figure 9.2.4.1   Work Screen of Initial Depths to Groundwater and Free Product

Part V. Process Monitoring

10.0 Soil Gas Monitoring

10.1 Background

The concentrations of three soil gas elements are of particular interest to the bioventing system: oxygen (O_2), carbon dioxide (CO_2), and total petroleum hydrocarbons (TPH). The O_2 and CO_2 concentrations in the ambient air are 20.9% and 0.05%, respectively. A lower O_2 concentration (typically less than 5%) and a higher CO_2 concentration (typically large than 10%) usually indicate active aerobic biodegradation in the soil and the existence of oxygen-limited conditions. This is due to the O_2 consumption and CO_2 generation by the microbial populations. For a site with a light hydrocarbon spill, such as fuels containing lighter compounds, the concentration of volatile hydrocarbons provides information on the contamination in the subsurface.

A soil gas survey point or a soil gas monitoring point is constructed by drilling a borehole at one location of a site using either a power driller or a hand-auger. Within the borehole, one or more screens are installed at different depths above the water table. Therefore, one or more soil gas samples are taken at different depths from one soil gas monitoring point.

The Soil Gas Monitoring section of the Bioventing Design Tool stores the field data and presents them from two perspectives: concentrations of soil gas elements at the same date and time but various locations, and variations of soil gas concentrations in a period of time at one particular monitoring point. Data collected from different depths of a soil gas monitoring point are presented together for convenience in processing and reviewing.

10.2 Tutorial

The *Soil Gas Monitoring* section is composed of two subsections: Soil Gas Monitoring Field Data and Soil Gas Monitoring Summary. The first subsection is designed for field data collection and data input, with all data collected at the same time on one page. The second subsection is for reviewing only. It is a pivot table of the first subsection data. The details of each subsection are described in Section 10.2.1 and 10.2.2.

10.2.1 Soil Gas Monitoring Field Data Input

The work screen for Soil Gas Monitoring is shown in Figure 10.2.1.1. It is composed of six command buttons, one list box, two input areas, and one data table. All the buttons are self-explanatory except the **Data Summary** button. The discussion on Data Summary is provided in Section 10.2.2.

To begin the input, a user needs to select the date and time from the list box in the middle of the screen. If the date and time information is not available, the list name is shown as "DATE x", where x is from 1 to 20 which corresponds to 20 pages of data at different date and time. For example, Page 16 in Figure 10.2.1.2 has not been specified. After selecting a page, a new date and time can be inputted at **Date and Time** area. The input format is mm/dd/yr hr:mm, where mm/dd/yr stands for month/day/year, and hh:mm for hour:minute. Note that there is a blank space between date and time. The newly inputted data and time will become the list name as soon as the screen is switched to another page.

The operator names are inputted at **Operator(s)** area. These names can be different on each page, and are inputted for every page.

Monitoring Point ID	Depth (ft)	Readings			Pump Pressure (in Hg)	Comments
		O₂ (%)	CO₂ (%)	TPH (ppm)		
mp-1	3.0	2.00	7.50	4500		
mp-1	6.0	2.50	6.50	3200		
mp-1	8.0	3.00	5.00	1200		
mp-1	10.0	NM	NM	NM		Water was encountered at this depth
mp-2	3.0	0.50	6.50	2200		
mp-2	6.0	3.00	6.50	1200		
mp-2	10.0	2.50	6.50	1180		
mp-3	4.0	1.00	10.00	20000		
mp-3	8.0	2.00	9.50	10000		
mp-3	10.0	3.00	9.00	10000		
mp-4	4.0	0.50	8.00	9500		
mp-4	8.0	1.00	8.50	8000		

Figure 10.2.1.1   Soil Gas Monitoring Input Work Screen

Figure 10.2.1.2   Selecting a Page in Soil Gas Monitoring

In the data table, a total of 15 data sets of soil gas monitoring samples can be recorded on one page. That means a total of 15 depths from all monitoring points can be recorded on one page. The information on Monitoring Point ID and Depth does not change on each page. They are inputted once and used by all 20 pages. If a monitoring point is installed during the soil gas monitoring process, as long as there is still space available in the table, the new monitoring point ID and depth can be added to the table.

If you click the **Clear** button, all contents including the monitoring point IDs and depths are cleared. If you want to clear only part of the table contents, highlight the area using either a mouse or an arrow key and click the **Delete** button on the keyboard.

Because of the space limitation of a computer screen in VGA mode, we limit the number of depths for each monitoring point to eight, which is more than enough at most sites. If more than eight depths are specified for one monitoring point, when a user clicks the **Data Summary** button, the following warning message appears. A correction must be made before entering the Data Summary section.
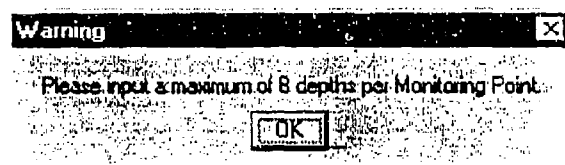

Figure 10.2.1.3   A Warning Message on Exceeding the Number of Depths Limitation

Soil Gas Monitoring

Site Name: Site 11

Operator(s): M. Smith   Date and Time: 4/20/96 12:30

Monitoring Point ID	Depth (ft)	Readings			Pump Pressure (in Hg)	Comments
		O₂ (%)	CO₂ (%)	TPH (ppm)		
mp-1	3.0	2.00	7.50	4500		
mp-1	6.0	2.50	6.50	3200		
mp-1	8.0	3.00	5.00	1200		
mp-1	10.0	NM	NM	NM		Water was encountered at this depth
mp-2	3.0	0.30	6.50	2200		
mp-2	6.0	3.00	6.50	1200		
mp-2	10.0	2.50	6.50	1180		
mp-3	4.0	1.00	10.00	20000		
mp-3	8.0	2.00	9.50	10000		
mp-3	10.0	3.00	9.00	10000		
mp-4	4.0	0.50	8.00	9500		
mp-4	8.0	1.00	8.50	8000		

Figure 10.2.1.4   Printout of Soil Gas Monitoring

Figure 10.2.1.4 shows a printout of Soil Gas Monitoring. One page of data can be printed out at a time.

10.2.2   Soil Gas Monitoring Data Summary Table

The Soil Gas Monitoring Summary data table is in fact a pivot table of field data inputted previously. The data of one particular element at one specific monitoring point is tabulated in the format of date and time versus depth. The variation of soil gas concentration over a period of time can be examined from this table. The work screen of the Soil Gas Monitoring Data Summary table is shown in Figure 10.2.2.1.

The data summary table is for viewing and printing only. A user can modify only the data from Soil Gas Monitoring work screen. By selecting the monitoring point and soil gas element, a set of soil gas data is retrieved from the master data table. There are three choices for soil gas element: C_2, CO_2, and TPH. They can be selected from the **Element** list box.

The number of available monitoring point selections in the **Monitoring Point** list box varies, depending on how many monitoring points are monitored. If there are only a few monitoring points available, blank names are shown in the list box. For example, there are only four monitoring points available in Figure 10.2.2.2. The remaining part of the list box is filled with blanks. By selecting those blank list names, a table without data will show up.

Print   Soil Gas Data Summary   << Back

Site Name: Site 11

Element: O2 (%)   Monitoring Point: mp-2

Date & Time	Depth (ft)						
	3.0	6.0	10.0				
4/20/96 12:30	0.5	3.0	2.5				
5/1/96 0:00	2.0	2.5	0.0				
4/4/96 0:00	0.0	0.0	0.0				
4/4/96 0:00	0.0	0.0	0.0				
5/5/96 0:00	0.0	0.0	0.0				
3/2/96 15:00	0.0	0.0	0.0				
5/5/96 0:00	0.0	0.0	0.0				
5/1/96 12:55	0.0	0.0	0.0				
9/9/96 0:00	9.0	9.0	9.0				
9/9/96 0:00	10.0	10.0	10.0				
9/9/96 0:00	0.0	0.0	0.0				
9/9/96 0:00	0.0	0.0	0.0				
9/9/96 0:00	0.0	0.0	0.0				

Figure 10.2.2.1   Work Screen of Soil Gas Monitoring Data Summary Table

Print   Soil Gas Data Summary   << Back

Site Name: Site 11

Element: O2 (%)   Monitoring Point: mp-2

Date & Time	Depth (ft)				mp-1		
	3.0	6.0	10.0		mp-3		
4/20/96 12:30	0.5	3.0	2.5		mp-4		
5/1/96 0:00	2.0	2.5	0.0				
4/4/96 0:00	0.0	0.0	0.0				
4/4/96 0:00	0.0	0.0	0.0				
5/5/96 0:00	0.0	0.0	0.0				
3/2/96 15:00	0.0	0.0	0.0				
5/5/96 0:00	0.0	0.0	0.0				
5/1/96 12:55	0.0	0.0	0.0				
9/9/96 0:00	9.0	9.0	9.0				
9/9/96 0:00	10.0	10.0	10.0				
9/9/96 0:00	0.0	0.0	0.0				
9/9/96 0:00	0.0	0.0	0.0				
9/9/96 0:00	0.0	0.0	0.0				

Figure 10.2.2.2   Selecting a Monitoring Point in Soil Gas Monitoring Data Summary Table

10.2.3 Tips and Tricks

a.   Although there is no requirement to group the depths of the same monitoring points together in
the Soil Gas Monitoring table, it is easier to review the data. If the user decides to group the
same depths of different monitoring points together, the data display in the data summary table
is not affected. The BVDT groups data by monitoring point ID in the data summary table.

b. When entering field data, it is recommended to use the available pages consecutively instead of jumping from one page to another because the BVDT does not sort the data for you. When a user does not input data to pages, blank rows appear between rows filled with data. It affects the appearance of the data summary table.

c. The proper input of date and time in Field Data Input is important. If the date and time is not provided, the entire row in the Summary table becomes blank. Because the BVDT assumes there is no data available from that particular page.

d. A field work sheet can be produced easily from the Soil Gas Monitoring input section. After inputting the monitoring point ID and depth, click the **Print** button. A blank soil gas monitoring work sheet with site-specific monitoring points and depths information becomes available. The blank work sheet has the same format as the BVDT computer worksheet. Thus, faster data analysis can be achieved.

11.0 Periodic In Situ Respiration Test

At some remediation sites, especially with a long-term pilot test, the soil gas is monitored over a period of time. Before the blower is shut down, a periodic in situ respiration test is conducted. The periodic in situ respiration test is very similar to the conventional in situ respiration test, except there is no helium gas injection. Therefore, the Periodic In Situ Respiration Test section in the BVDT is the same as conventional In Situ Respiration Test section except there is no helium information in the table. A work screen is shown in Figure 11.1. The details on how to use the Periodic In Situ Respiration Test can be referred to in Section 5.0.
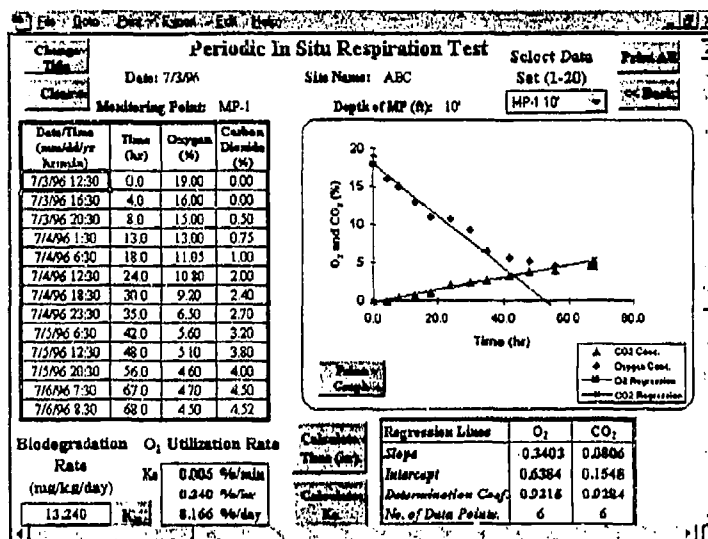
Figure 11.1. Periodic In Situ Respiration Test Work Screen

Part VI. Database

12.0 Database

As the result of Bioventing Initiative sponsored by the U.S. Air Force Center for Environmental Excellence (AFCEE) Technology Transfer Division, valuable information from more than 130 bioventing sites around the United States has been collected. Battelle has been compiling the key parameters at all of these sites into one bioventing database for researchers and environmental engineers to use. During the construction of various field bioventing systems, Battelle created a database of equipment and their vendors. Both databases are presented in the Bioventing Design Tool as a reference.

12.1 Bioventing Case Study Database

The Bioventing Initiative Case Study Database is composed of three parts (Figure 12.1.1): *Open An Existing Bioventing Site*, *Modify An Existing Bioventing Site*, and *Add A New Bioventing Site*. The first one is a collection of the information from 130 bioventing initiative sites at present. The second one is for modifying any incomplete or incorrect information in the database. The last one is for adding new site information the users collected from their own projects. We encourage users to submit data to us so that we can enter your data into the database for distribution to all bioventing professionals in the country in later releases of the BVDT. The data can be submitted to George Yu, Battelle Memorial Institute, 505 King Avenue, Columbus, Ohio 43201, USA, Tel: (614)424-3639, Fax: (614)424-3667, Email: yug@battelle.org.us.
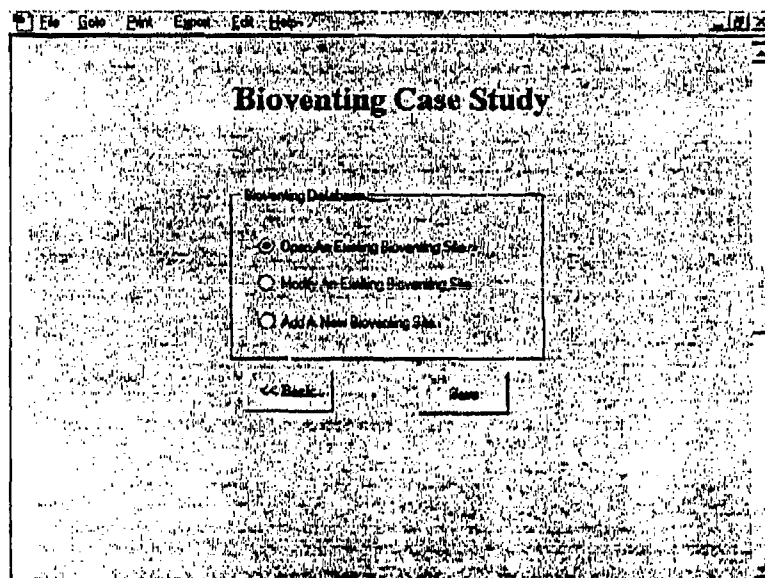
Figure 12.1.1   Bioventing Case Study Work Screen

12.1.1 Open An Existing Bioventing Site

Figure 12.1.1.1 shows the Bioventing Case Study table generated by the BVDT database. There are ten categories of information available in the table: Fuel Contamination Type; depth to groundwater and contamination; physical, chemical, and microbial characterizations of contaminant; changes of contamination concentration; vent well data; monitoring point data; blower data, and comments.

Users can search the information of a particular site by clicking the list box next to the *Select A Site* list box (Figure 12.1.1.2). By moving the vertical scrolling bar, the list of all sites in the database is presented. To select a specific site, move the cursor into the list box (move toward left) so that the list you are interested in is highlighted, and click the left mouse button to select it. The information about that site is shown in the table. The table can be printed out by clicking the Print button to a default printer.

Because of the layout of the table, one computer screen does not have enough space to display the entire table. Users access half the table at a time. You can switch from top part of the table to the bottom part by clicking the downward arrow button in the middle of right-hand side of the work screen. To move back to the top part from the bottom part, clicking the upperward arrow button in the lower part of the right-hand side will accomplish this. This partial access to the table does not affect the printout of the table, which is printed onto one 8½ x 11 sheet of paper.

All the information in this window is read-only. To modify the information in the database, you need to click the **Modification** button to access the **Bioventing Case Modification** section, which is the topic in Section 12.1.3. It should be noted that by clicking the **Modification** button within *Open An Existing Bioventing Site* section, users gain access to the **Bioventing Case Modification** work screen immediately; by clicking *Modify An Existing Bioventing Site* check box from the *Bioventing Case Study* level, users are asked to select a site first, and then gain the access to the **Bioventing Case Modification** work screen in Section 12.1.2.

Bioventing Case Study

Site Name : AFP4, TX: FSA-1

Fuel Contamination Type				Depth bgl (ft)	
JP-4, 7 & JP-5 Jeft fuel				**Groundwater**	**Free Product**
				23	24
Physical Characterization		**Chemical Characterization** (mg/kg)		**Microbial Characterization** (% O₂/day)	
Particle Size (%)		Iron	7450	Initial Rate	27.6
	Gravel	Alkalinity	210	Mid Rate	0.05
	Sand	36	pH (no unit)	8.8	Final Rate	0.14
	Silt	44	TKN	33		
	Clay	20	Phosphorus	267		
Soil Gas Permeability (darcy)	0.6				
Radius of Influence (ft)	20				
Moisture Content (% by wt)	13.7				

				Initial	Final
Contamination (mg/kg)			Date	3/5/93	5/26/94
			Benzene	0.36	0.03
			Toluene	1.27	0.03
			Ethylbenzene	11.68	0.03
			Xylene	31.34	0.03
			BTEX	44.65	0.12
			TPH	29.17	684.43

Vent Wells			Monitoring Points		
	Installed Wells	**Existing Wells**	**No of MPs**	**Screen Depth (ft)**	**Spacing from Vent Well (ft)**
			3		
Number of Wells	1		MPA	5;14;19	5
Diameter (in)	4		MPB	5;14;19	10
Screened Interval (ft)	15		MPC	5;14;19	20
Total Depth (ft)	25		MPD		
			MPE		

Blower Type and Configuration	
Type	Configuration
1 hp Gast regenerative; Flow rate: 10 cfm; Initiation: 4/19/93	Injectioin

Comment	

Figure 12.1.1.1   Example of Bioventing Case Study

Figure 12.1.1.2   Bioventing Case Study Work Screen

12.1.2 Modifying An Existing Bioventing Site

When selecting *Modify An Existing Bioventing*, users will be asked to confirm or select a site to be modified as shown in Figure 12.1.2.1. Then the **Bioventing Case Modification** window shows up (Figure 12.1.2.2). Besides the different background color (light green versus light yellow), the format of the table, including the upward and downward buttons, in this window is same as the table in Figure 12.1.1.1.

Figure 12.1.2.1   Selecting or Confirming an Existing Site Name

Figure 12.1.2.2   Bioventing Case Modification Work Screen

There are five buttons in the Figure 12.1.2.2 window: **<<Back, Case Study, Select, Delete,** and **Save.** The **Case Study** button provides a gateway back to the **Bioventing Case Study** section discussed in Section 12.1.1. The **Select** button brings up the list of all sites in the database (Figure 12.1.2.1). The user scrolls down to find the sight. After the site name is chosen, the site information is retrieved from the database. The information from the selected site will not appear until the dialog box of Figure 12.1.2.1 disappears. When a new site is selected, the information on the table for the current site will be retrieved and updated in the database before displaying the information of the new site.

The **Delete** button in Figure 12.1.2.2 brings up a confirmation dialog box as shown in Figure 12.1.2.3. This operation takes some time too, but is faster than the **Select** button. If a record of a site is removed from the database, it is permanently removed from the list.

Figure 12.1.2.3   Confirm Deletion of a Site from Database

12.1.3 Add A New Bioventing Site

To add new bioventing site information to the database, a user clicks the *Add A New Bioventing Site* check box in Bioventing Case Study section (Figure 12.1.1). First, the user will be prompted for the name of the site as shown in Figure 12.1.3.1. If it is a nonmilitary site, the city name should be inputted under the Base name. If it is a foreign country, select *Foreign* from State name, and type the city and country in the Base. See an example in Figure 12.1.3.2.

After all in the information is inputted, click the **OK** button, and the **Bioventing Case Modification** window will show up (Figure 12.1.2.2). The combining text string of Base, State, and Site will become the official name in the database. For example, the official name for the site shown in Figure 12.1.3.1 is "Battelle, Ohio: Test Site." All the sites are sorted in the order of Base, State, and Site.
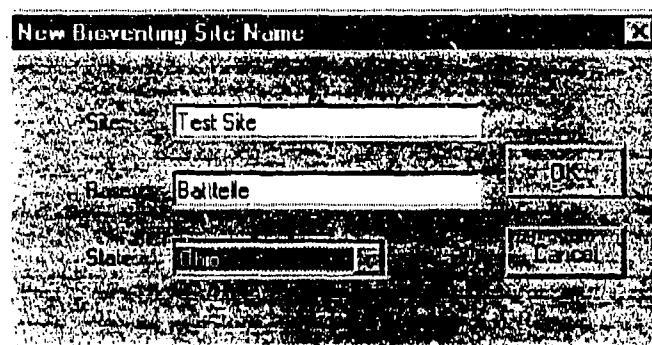
Figure 12.1.3.1   Creating a New Bioventing Site Name (Domestic)
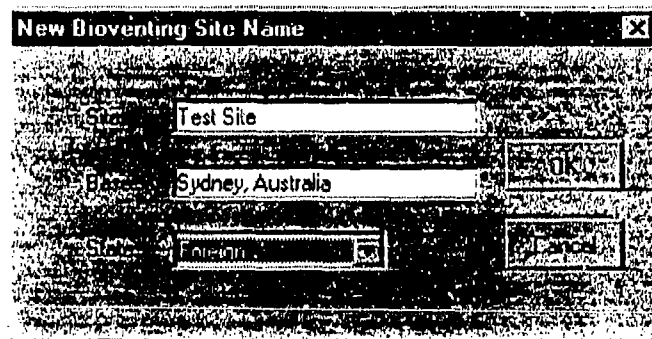
Figure 12.1.3.2   Creating a New Bioventing Site Name (Foreign)

12.1.4 Tips and Tricks

a)   The operations of retrieving (**Select** button) and deleting (**Delete** button) a record in the existing database can take a long time. For an Intel 486 66 MHz PC, it takes 30 seconds for modifying and 15 seconds for deleting; and for an Intel 586 120 MHz PC, it takes 14 seconds and 3 seconds, respectively.

b)   The site information can be printed only by selecting **Open An Existing Bioventing Site** (Section 12.1.1). This forces the user to retrieve the new site information after entering it and to validate its accuracy.

12.2 Bioventing Equipment Database

The equipment database is composed of two database tables: Equipment Item and Vendors. The Equipment Item table includes the following information: equipment name, vendor name, vendor stock number, price, main category, subcategory, and usage. The Equipment Vendor table includes vendor name, contact person name, street name, city name, state name, zip code, phone number, and fax number. The equipment name in both tables builds up the link between the two database tables.

For ease in searching, we categorize all equipment by main ategories and subcategories in alphabetical order. The current main category includes:

> Air compressor
> Auger equipment
> Bailer
> Ball valve
> Blower
> Blower filter
> Brass sleeves
> Calibration gases
> Casing
> Demolition
> Fluke thermometer
> Gas analysis instrument
> Identification tags
> Instrumentation
> Interface probe
> Magnehelic gauge
> Manhole
> Monitoring point installation
> Piping supplies
> Portable generator
> Pressure gauge
> Quick connectors
> Riser
> Rotameter
> Screen
> Soil gas analysis
> Soil gas sampling
> Soil gas sampling rod
> Soil moisture equipment
> Suction strainer
> Tedlar bags

Thermocouples
Trenching
Tubing
Well filler material

The current sub category includes:

1:1 Diluter
10% Carbon dioxide
10% Oxygen
10:1 Diluter
4400 ppm hexane
4800 ppm n-hexane
5% Carbon dioxide
500 ppm n-hexane
Air compressor
Air flow
Anemometer
Auger cross handle
Auger extensions
Auger head
Bailer
Ball valve
Bentonite chips
Blower
Blower filter
Brass sleeves 2 in × 12 in
Brass sleeves 2 in × 3 in
Brass sleeves 2 in × 6 in
Brass tags
Carry case
Casing
Cement
Combustion sampling meter
Demolition
Diaphragm pump 1/16 HP
Diaphragm pump 1/3 HP
Fluke thermometer
Generator wheel kit
Helium 99.999% purity
Helium detector
Helium industrial grade
Instrumentation
Interface probe
Latex tubing
Magnehelic gauge
Manhole
Nylon tubing
Oxygen/Carbon dioxide meter

Pipe fitting
Plastic end caps
Portable generator
Pressure gauge
PVC cement
PVC piping supplies
PVC primer
Quick connector coupler
Quick connector plug
Riser
Rotameter
Screen
Silica sand
Slide hammer
Soil gas analysis
Soil gas sampling
Soil moisture blocks
Soil moisture meter
Soil sampling
Stamping kit
Suction strainer
Tedlar bags, 1 liter
Teflon tape
Thermocouple cable
Thermocouple plugs
TraceTechtor
Trenching
Water trap
Well cover

These lists of main category and subcategory equipment are useful in searching for more obscure pieces of equipment. For example, Figure 12.2.1.1 shows items related to quick connector couplers such as the diluter for the TPH meter.

Similar to the Bioventing Case Study, users can update the equipment database based on their experience. If the user would like us to include additional equipment information into the database, please write to us (see address in Section 12.1).

The Equipment Database is divided into two subsections (Figure 12.2.1): *Search By* and *Update*. Users can search the equipment based on the information of Equipment Name, Main Category, Sub Category, and Vendor. The database upgrade is conducted from four perspectives: Equipment Item, Vendor, Main Category, and Sub Category.
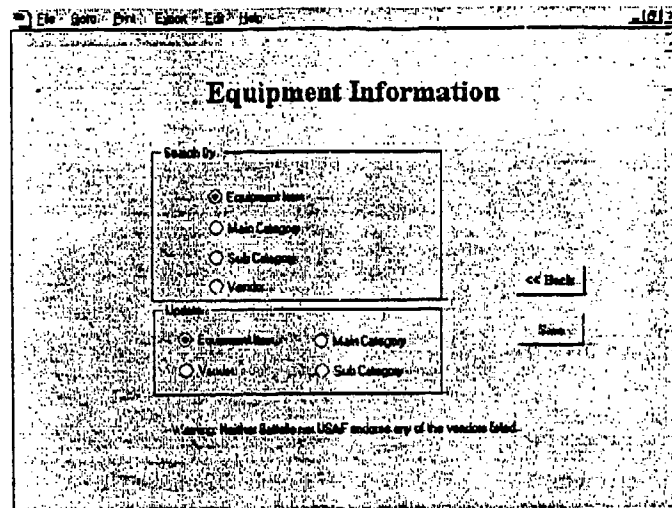
Figure 12.2.1   Equipment Database Work Screen

12.2.1 Search by Equipment Item

Figure 12.2.1.1 shows the work screen for searching by Equipment Item. The window in the middle of the screen lists all the equipment items currently stored in the database. By clicking the left mouse button and highlighting the item you are interested in, all the information related to the individual piece of equipment is retrieved from the database displayed on the screen.
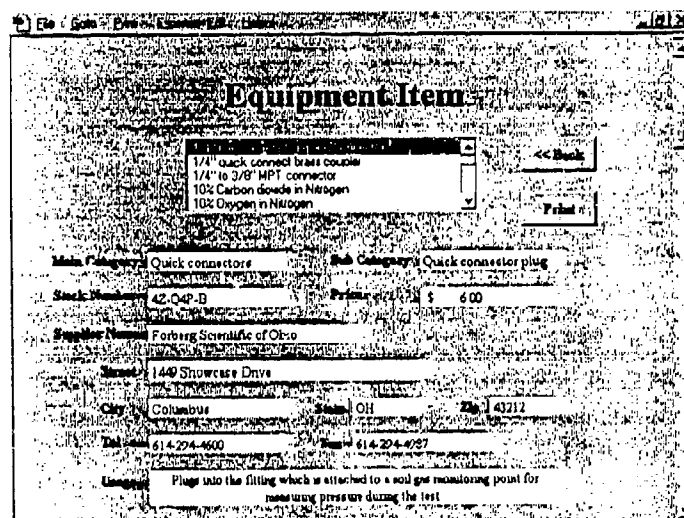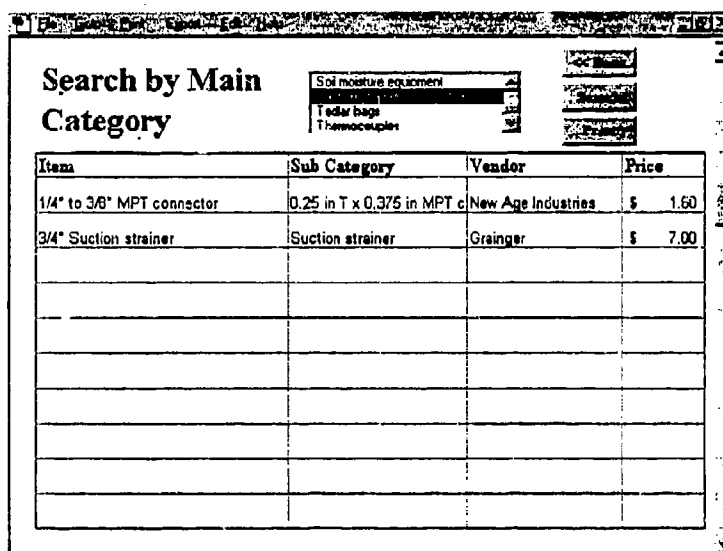
Figure 12.2.1.1   Work Screen for Searching by Equipment Item

12.2.2 Search by Equipment Main Category

Figure 12.2.2.1 shows the equipment work screen for Search by Main Category. The searching criterion is the main category name. After selecting the main category name from the list box at the top of the screen, clicking the **Search** button activates the searching activity. The result of this search is displayed in the table in the middle of the screen. There are four columns in the table: Equipment Item, Sub Category, Vendor, and Price.

The reason for using the **Search** button is that there are more than one equipment items matching the search criterion. A different search algorithm is used in searching by Main Category, Sub Category, and Vendor from that in the Equipment Item Screen. There is only one entry of the same equipment item in the database. If a user needs to store more than one vendor of the same equipment item, try to use a slightly different name so that the database will treat them as two different entries; the main and sub category can be the same. For example, if there are two diaphragm pumps, one is 1/16 HP and the other one is 1/3 HP. We can call them Diaphragm Pump 1/16 HP and Diaphragm Pump 1/3 HP, and they will be considered as two different equipment items in the database.

Figure 12.2.2.1   Work Screen for Search by Main Category

12.2.3 Search by Equipment Subcategory

Figure 12.2.3.1 shows the equipment work screen for Search by Sub Category. The searching criterion is the subcategory name. After selecting the subcategory name from the list box at the top of the screen, clicking the **Search** button activates the searching activity. The result of this search is displayed in the table in the middle of the screen. There are four columns in the table: Item, Main Category, Vendor and Price.

Figure 12.2.3.1   Work Screen for Search by Subcategory

12.2.4 Search by Equipment Vendor

Figure 12.2.4.1 shows the equipment work screen for Search by Vendor. The searching criterion is the vendor name. After selecting the vendor name from the list box at the top of the screen, clicking the **Search** button activates the searching activity. The result of this search is displayed in the table in the middle of the screen. There are four columns in the table: Item, Main Category, Sub Category and Price.

Figure 12.2.4.1   Work Screen for Search by Equipment Vendor

12.2.5 Update Equipment Item

Figure 12.2.5.1 shows the dialog box for updating Equipment Item. All the fields (columns) in the equipment item database table are listed. There are several ways of selecting an equipment item.

a) using either arrows or scroll bar on the right-hand side of the dialog box to find the desired equipment item.

b) Clicking the Criteria button to do a search with certain criteria (Figure 12.2.5.2).

c) Clicking Find Prev and Find Next buttons to access previous and next equipment items. After modifying the contents of the entry in each field, click the Close button to update the database and close the dialog box.

Figure 12.2.5.1   Work Screen for Update Equipment Item

When the dialog box is in the search mode (the Criteria button is replaced by the Form button), after typing criteria in various fields, click either Find Prev or Find Next button. The search result will be shown as in Figure 12.2.5.1. For a simple table, one criterion is enough. When it is in the search mode, clicking the Form button will bring the dialog box back to the format of Figure 12.2.5.2.
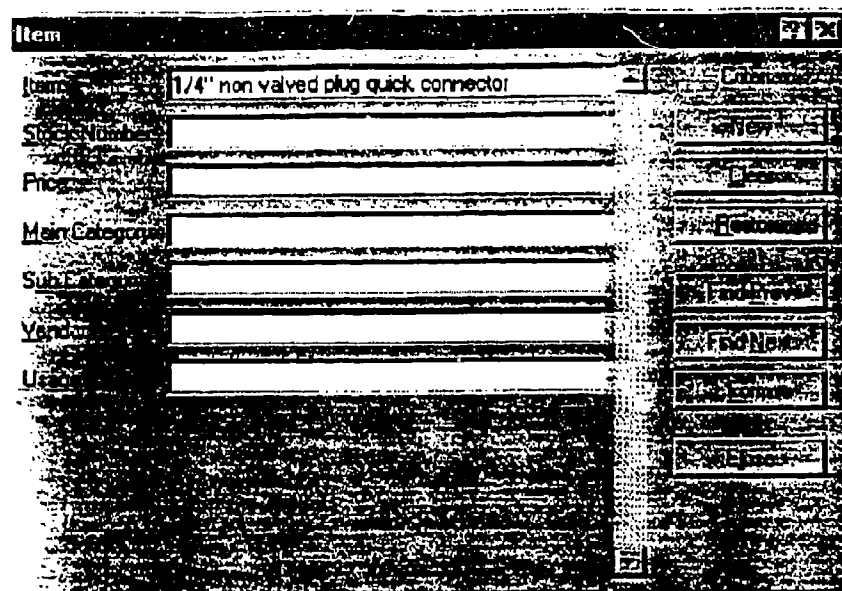
Figure 12.2.5.2   Work Screen for Setting Up Search Criterion

The New button will bring up a blank dialog box for inputting. After all information has been entered, click the Close button to close the dialog box or the New button for another entry. Clicking the Delete button brings up a warning message to confirm the permanent deletion of the record from the database (Figure 12.2.5.3).
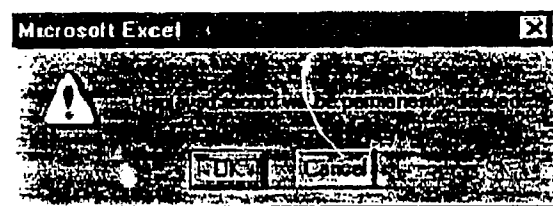
Figure 12.2.5.3   A Warning Message Before Deleting an Entry in the Database

12.2.6 Update Vendor Information

Figure 12.2.6.1 shows the dialog box for updating vendor information. All the fields (columns) in the vendor database table are listed. The basic usage of this dialog box is the same as the updating equipment item described in Section 12.2.5.

Figure 12.2.6.1   Work Screen for Updating Vendor Information

12.2.7 Update Main Category and Sub Category

Figures 12.2.7.1 and 12.2.7.2 show the dialog boxes for upgrading Main Category and Sub Category. The basic usage of this dialog box is the same as updating equipment item described in Section 12.2.5.

Figure 12.2.7.1   Work Screen for Updating Main Category
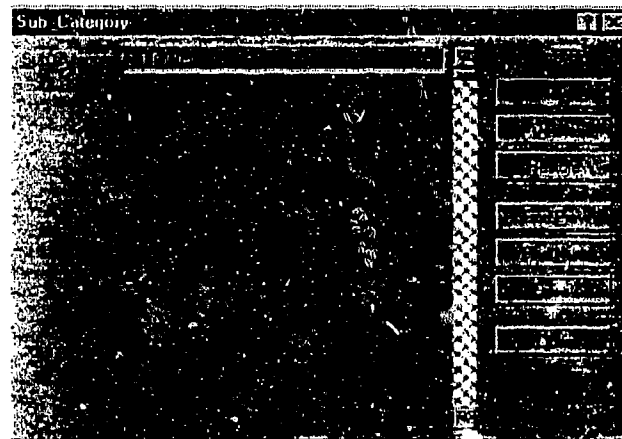
Figure 12.2.7.2   Work Screen for Upda ing Subcategory

12.2.8 Tips and Tricks

There is only one field in both the Main Category and Sub Category tables. They are used for searching equipment items that meet the criteria in these two categories. It is important to spell the category name in these two tables exactly the same as it appears in the equipment item table.

13.0 References

Leeson, A and Hinchee, R. E. 1995. *Principles and Practices of Bioventing*, Prepared for USAF Environics Directorate of the Armstrong Laboratory, Tyndall AFB. FL and National Risk Management Research Laboratory of US EPA, Cincinnati, OH.

Peck, Ralph B. et al. *Soil Mechanics in Engineering Practice*, New York, Wiley, 1967.

Appendix A: Glossary

Bentonite[1]
Clay composed of volcanic ash decomposition which is used to seal wells (hole plug).

Biodegradation[1]
The act of breaking down material (usually into more innocuous forms) by natural processes of living things such as metabolization by microorganisms.

Biodegradation Rate[1]
The mass of contaminant metabolized by microorganisms per unit time. In soil contamination this is normalized to the mass of soil and is usually expressed as *mg contaminant degraded/kg soil-day (mg/kg-day)*.

Bioremediation[1]
General Term for the technology of using biological processes such as microbial metabolism to degrade soil and water contaminants and decontaminate sites.

Biovent Case Study Database
Data sets which contains information taken from previous bioventing sites.

Bioventing[1]
The process of aerating vadose zone by means of installed vent wells to stimulate in situ biodegradation of aerobically degradable contaminants.

Blower[1]
Equipment which produces a constant stream of forced air. Blowers are sized in terms of horsepower.

BVCE
Bioventing Cost Estimator. The computer tool to estimate the cost of a bioventing site.

Contaminant[1]
Something that makes material in contact with it impure, unfit, or unsafe; a pollutant.

CSV
Comma-separated values file. The space for that cell is eliminated in the CSV file. If the text is long and contains blank spaces, the text will be exported by a pair of quotation marks surrounding the test string.

Dialog Box
A dialog box is a pop-up window used to input text, select a check button, or bring up another window. It is usually invoked by a menu, a button, or another dialog box

Diffusivity[1]
Diffusion coefficient; the amount of material, in grams, which diffuses across and area of 1 square centimeter in 1 second due to a unit concentration gradient, (particular to compound and medium pair).

Dynamic Method
Calculate soil gas permeability for sites where the pressure response at monitoring points changes slowly during the permeability test (i.e. >1 hour to reach a steady pressure). Typically, this may be in fine sand soils to clays where the screened interval extends to depths of more than 10 feet and when monitoring points are screened at depths of 10 feet or greater.

Equipment Database
Database which contains the list of Equipment necessary for Bioventing.

Information Box or Message Box
An information box or a message box is a pop-up window to inform the users. Usually no further action is required. The information box can be closed by clicking the **OK** button.

Initial Soil Gas Readings
Used to record the soil gas data before the respiration test.

In Situ Respiration Test[1]
Test used to provide rapid field measurement of in situ biodegradation rates to determine the potential applicability of bioventing at a contaminated site and to provide information for a full-scale bioventing system design.

Linear Regression Line
Uses the "least squares" method to calculate a straight line that best fits your data and returns an array that describes the line.

List Box
A list box is another format common to Windows programs. By clicking the arrow on the right-hand side of the list box, a list is displayed. Users move the mouse cursor to highlight and make selection. If there are more selections than the window can display, a vertical scroll bar shows up. Users can select the hidden list by moving the scroll bar.

Oxygen Utilization Rate[1]
Rate of reduction of the in situ oxygen content of soil gas due primarily to biological processes.

Page
A page refers to one set of data presented in a work screen

Permeability[1]
Measure of the ability of liquid or gas to move through soil.

Pilot Test
A small scale system constructed to determine site characterization and information for use in the design and construction of a full scale system. Pilot tests are also used to determine if a system is feasible for use at a specific site.

Porosity[1]
Measure of the amount of available space In soil through which liquid and gas can move.

Radius of Influence[1]
The maximum distance from the air extraction or injection well where vacuum or pressure (soil gas movement) occurs.

Respiration Rate[1]
see oxygen utilization rate

Screened Interval
The portion of the well which permits groundwater or soil gas to flow into or out of the well. The screened interval is normally encased in a sand pack or gravel pack.

Soil Bulk Density
The mass of dry soil per volume usually measured in units of (g dry soil/cm^3) and denoted by the symbol ρ_k.

Steady-State Method[1]
Calculate soil gas permeability when use of dynamic method is inappropriate as in cases when the pressure response at monitoring points is rapid during the permeability test (i.e. <1 hr to reach a steady pressure). Radius of Influence must first be determined to calculate permeability using this method.

Vent Well[1]
A well designed to facilitate injection or extraction of air to/from a contaminated soil area.

Work Screen
A work screen is a computer monitor display. By using screen dump command (Alt+Print Screen), the work screen can be copied to the computer clipboard and pasted to any Windows program.

Note:

1. Leeson, A. and Hinchee, R. E. 1995. *Principles and Practices of Bioventing,* Prepared for USAF Environics Directorate of the Armstong Laboratory, Tyndall AFB, and National Risk Management Research Laboratory of US EPA, Cincinnati, OH.

Appendix B: Index